POWER PLANT ENGINEERING

Established Over 28 Years

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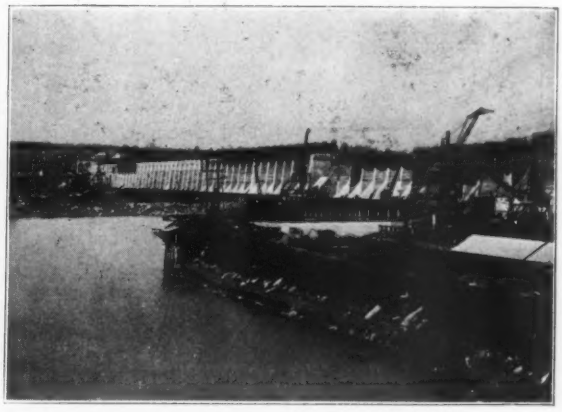


Corral for 600,000 Horses

IF YOU were offered the use of those horses free, provided you could arrange to keep them under control and find something for them to do, it would look like a gold mine. But that's a lot of horsepower. It would take a big enclosure. And where could you find work for 300,000 teams?

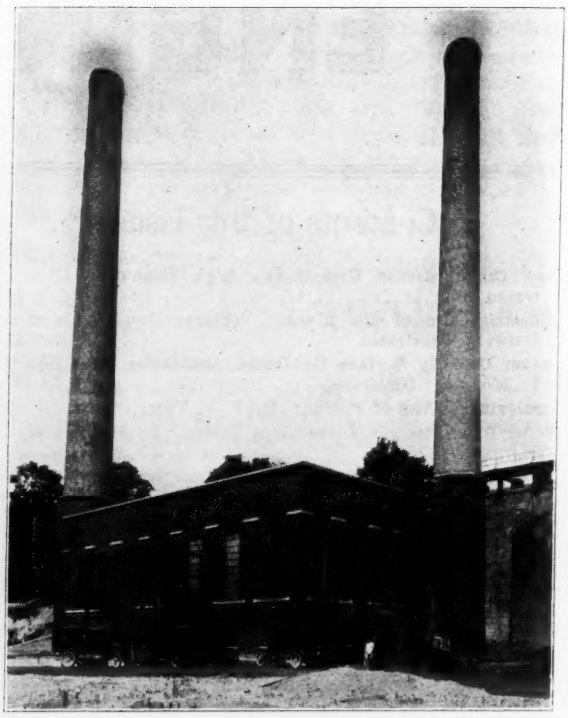
That's one of Uncle Sam's problems right now. He has the corral well under way; the horses are waiting at Muscle Shoals. Where's the work to come from? The Wilson Dam, shown above, is 780 ft. under a mile in length. The concrete used would make an 18-ft. road from Philadelphia to Chicago. And the 600,000 horses, placed nose to tail would just about reach the same distance. Uncle Sam will finish the corral. He will have the horses safely inside, ready to work. Then what? Here's one of the biggest power problems of today. And we are all part owners. An article over farther in this issue tells something more about it.

FIVE MILLIONTHS of a second ordinarily is not considered a long interval of time. In that time a modern high-speed rifle bullet would travel only seven one-thousanths of an inch. The earth in its terrific course through space would move only two-tenths of an inch. Obviously, a thing would have to move pretty fast to get away from us in five one-millionths of a second.

Some things *do* move pretty fast, however, and in dealing with such things five-millionths of a second may seem a long time. On page 1151, for instance, you will find that in the design of lightning arresters, a delay of five-millionths of a second represents the entire difference between perfect protection and non-protection.

New Crawfordsville Unit Shows High Economy

MUNICIPALLY OWNED PUBLIC SERVICE PLANT IN INDIANA INSTALLS A NEW 3000 KW. TURBO-GENERATOR WHICH SHOWS A STEAM CONSUMPTION OF LESS THAN FIFTEEN POUNDS PER KILOWATT HOUR. COAL CONSUMPTION IS CONSIDERABLY REDUCED



TO MEET A GRADUAL increase in demand beyond the maximum capacity of the installed equipment, the Crawfordsville municipal electric light and power plant early this spring somewhat enlarged its building and added equipment sufficient to increase the capacity by 3000 kw. This equipment includes a new Westinghouse 3750-kv.a. turbo-generator equipped with a Wheeler surface condenser and a 779-hp. Stirling boiler with all the necessary auxiliary equipment.

This plant serves a district including Crawfordsville, a city of approximately 10,000 population, Linden, New Richmond, Wingate, Waynetown, Darlington, Mace and Linsburg, Ind. The total population served is about 16,000. The plant carries the lighting and domestic load of all of this district and the industrial load in the city of Crawfordsville, which consists chiefly of the power requirements of three local brick plants, Crawfordsville Wire and Nail Mill, Umphrys Mfg. Co. and other smaller factories.

This plant, municipally owned and operated, was first put in commission in 1891. At that time it consisted of two 150-hp. Stirling boilers, equipped with hand-operated stokers, carrying a steam pressure of 100 lb., three arc lamp machines having a total capacity of 150 lamps of 2000 candle power each and one a.c. generator of 50 kw. capacity. The prime movers consisted of one 100 and one 125-hp. Westinghouse steam engine. In the spring of 1892, just a year later another 200-hp. Westinghouse engine and a 200-kw. generator were added to take care of the increased demand.

It is of interest to note that at this time the use of coal was discontinued and natural gas burners were installed under the boilers. Gas was used for a number of years but was later discontinued as it proved to be unsatisfactory owing to the inadequate supply.

Shortly after the reversion to coal the present plant was built. At the outset the equipment consisted of two 500-kw. General Electric turbo-generators, equipped with Alberger jet condensers, and three 350-hp. Stirling boilers equipped with mechanically operated over-feed stokers. In 1914 an additional 350-hp. boiler was installed and in 1919, a 1500-kw. General Electric turbo-generator, equipped with an Alberger jet condenser was added. At this time all the furnaces were re-equipped with Westinghouse underfeed stokers.

Coal bunkers are built into the side of this hill and a spur from the railroad is constructed directly over them. Gondola cars are spotted on this trestle and are dumped directly into the hopper. No power whatsoever is required for handling the coal; the feed from the coal car to the stoker hopper is effected entirely by gravity.

As shown in the plan view of the plant, the building is divided lengthwise into two rooms, the turbine room and the boiler room. That on the west side contains the turbines, condensers, and other turbine auxiliaries, switchboard, electrical apparatus and the chief engineer's office. The east room is devoted exclusively to the boilers and their auxiliary apparatus.

Immediately adjacent to the boiler room and under a new section of the coal bunker there are two small rooms; one contains the forced draft equipment and the other is used as a tool and storage room.

It will be noted that sufficient space has been left in the boiler room for the installation of another boiler unit should it be found expedient to put another one in at some future time.

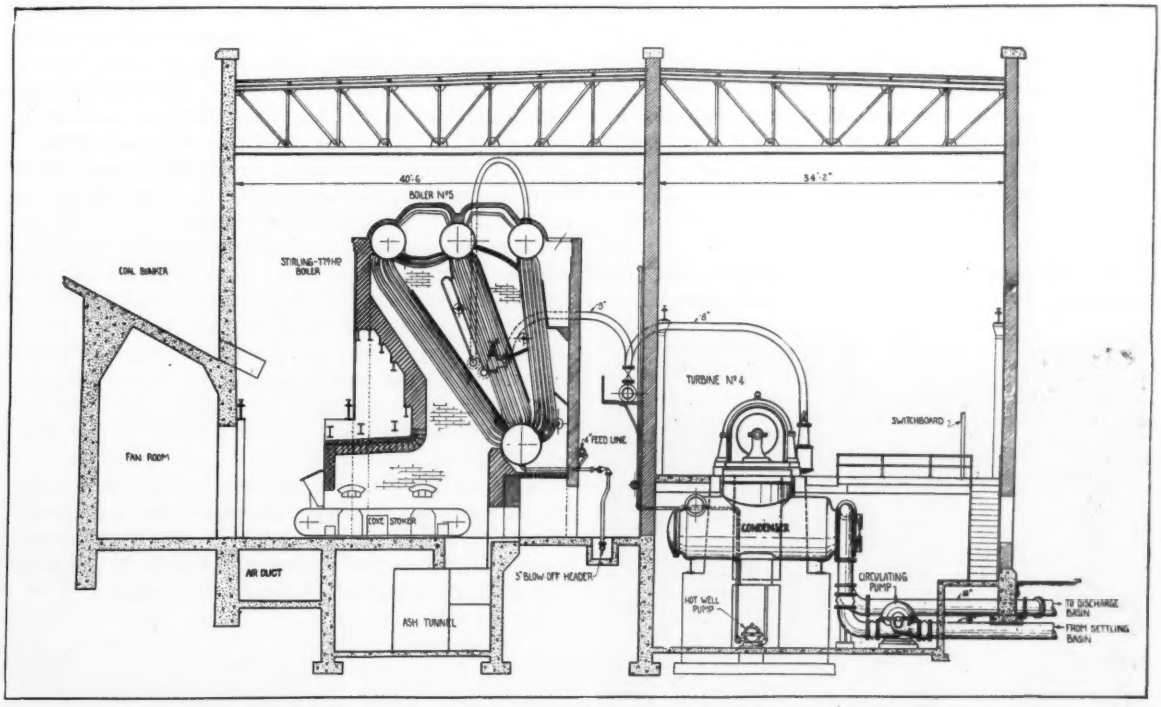


FIG. 1. SECTION THROUGH PLANT AT THE NEW TURBINE AND BOILER UNITS

NEW EQUIPMENT INCREASES CAPACITY TO 5500 KW.

To a large extent the new equipment is thermally isolated from the rest of the plant. Coal and ash handling equipment is common to both the old and the new plant. The electrical end, of course, ties in with the distribution system but the steam system is normally isolated, the two steam headers may, however, be tied together should operating conditions demand it.

Up until the present time the new turbo-generator has not been operated up to its maximum capacity but it is entirely likely that the load requirements will necessitate full load operation within the next year. This turbine is of the Westinghouse horizontal reaction straight condensing type with two impulse units, rated at 3000 kw. Direct connected to it, on the same shaft, is a Westinghouse 3-phase, 60-cycle, 2300-v. generator rated at 3750 kv.a.

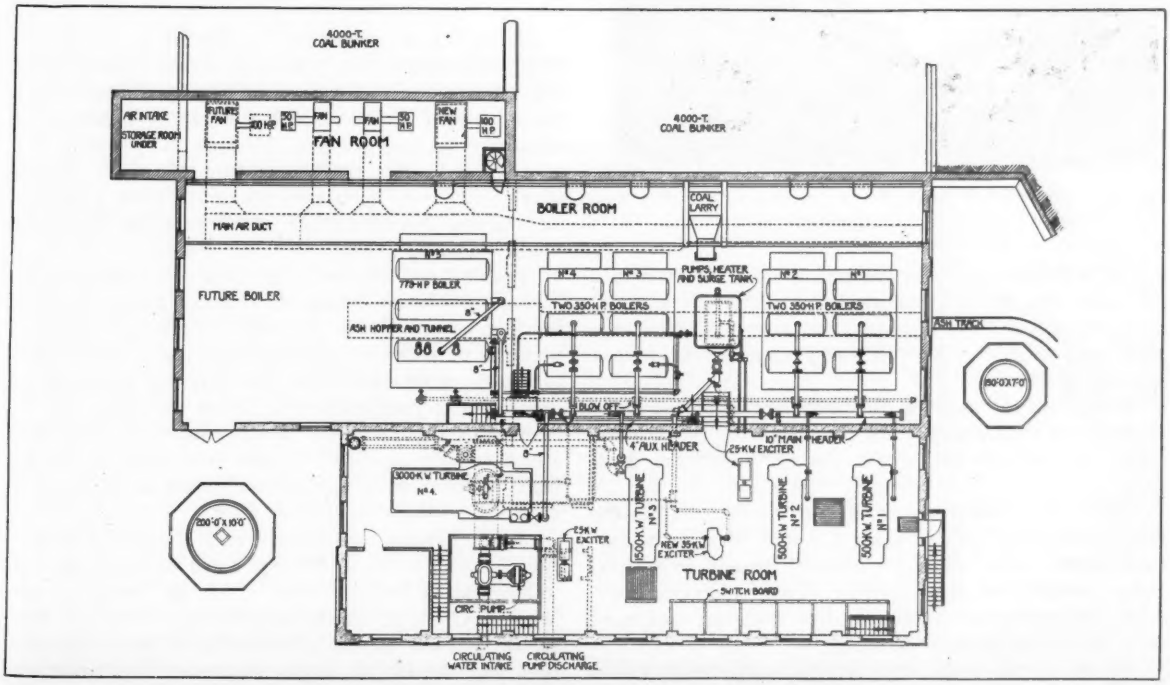


FIG. 2. SECTION THROUGH PLANT AT THE NEW TURBINE

or 3000 kw. at 80 per cent power factor. The full load current is 942 amp. per phase or 1630 amp. total.

Excitation is supplied by an independent exciter which runs at 1200 r.p.m. and delivers, at full load, 280 amp. at 125 v. to the main generator field. At rating this unit develops 35 kw. which amounts to about 1.1 per cent of the main generator output at rating. The compound wound generator is driven through reduction gearing by a Westinghouse non-condensing turbine which runs at 7260 r.p.m.

Two additional exciter units are installed in the plant; one, having a capacity of 25 kw., is direct connected to a

FIG. 3. CIRCULATING WATER SUPPLY AND DISCHARGE FOR 6000 SQ. FT. CONDENSER

Curtis non-condensing turbine and runs at 3600 r.p.m., the other, also of 25-kw. capacity, is driven by a direct connected General Electric induction motor which is supplied with current at 2300 v. and runs at a synchronous speed of 1200 r.p.m.

Ordinarily the steam-driven units are employed so as to obtain a satisfactory plant heat balance, the exhaust being required to obtain the desired feed-water temperature.

All of the control of this station is effected from the main switchboard located along the west wall of the turbine room. This board contains 21 panels, one panel being provided for each generator, exciter and outside circuit. The new panels and all the new electrical equipment is of Westinghouse manufacture.

Speed control of the main turbine is effected by means of an automatic speed governing device which is capable of maintaining the speed within 2 per cent of normal. It is also equipped with an emergency trip so arranged that if the speed exceeds the normal value by 10 per cent it acts to close the throttle valve. This valve is of the balanced type, of extra heavy construction, and is suitable for quick action and the use of superheated steam.

This unit takes steam at about 180 lb. gage and 100 deg. superheat and discharged into a vacuum of about 28½ in. of mercury, referred to a standard barometer. A Wheeler Condenser and Engineering Co. surface condenser is rigidly mounted on a concrete foundation directly below. The exhaust connection to the turbine is formed by a flexible copper expansion joint. The condenser is of the two-pass type and contains 6000 sq. ft. of cooling surface or 2 sq. ft. per kw. served. There are 1910 seamless brass drawn tubes of No. 18 B. W. G., ¾ in. diameter by 16 ft. long which make up this 6000 sq. ft. of surface.

Circulating water is pumped through the condenser from the intake pipe by a Wheeler 16-in. horizontal split casing brass fitted centrifugal circulating pump which operates under a total dynamic head of 31 ft. It is driven by a direct connected General Electric motor of 65 hp. capacity which runs at a synchronous speed of 600 r.p.m.

Condensate is removed by a 4-in. double suction 2½-in. discharge centrifugal hot well pump which operates under a total dynamic, suction and discharge head of 80 ft. It is driven by a direct-connected General Electric Curtis non-condensing turbine which at the rated speed of 1750 r.p.m. develops 6 hp. This unit takes steam at 100 lb. gage and 100 deg. superheat and at full load requires about 390 lb. per hr. Condensate is delivered direct to a surge tank which floats on the boiler-feed system.

Air and other non-condensable gases are removed from the condenser by means of a Wheeler two-stage multi-jet steam ejector.

Generator Air Washed by Spray

Cooling of the generator is effected by means of a Spray Engineering Co. open type air circulating system. The air is cooled and washed by passage through the fine spray or mist from a number of spray nozzles. This apparatus has a capacity of 1500 cu. ft. per min. which is sufficient to keep the temperature rise of the generator within allowable limits even under the most adverse circumstances. No air conditioning is supplied for the other smaller capacity generators in the plant.

Turbine and generator bearings are lubricated by a Richardson-Phenix bypass oil system. From the various bearings the oil drains to a sump in the base of the unit which is of sufficient capacity to permit of some settling to allow a certain amount of the entrained water and solid impurities to precipitate out. From the sump, the oil is pumped by a pump on the governor spindle through water-cooled coils by as direct a route as possible, to the bearings. A portion of the oil in circulation is continually bypassed through a gravity filter.

Steam for the new turbine unit is supplied by a new type Stirling boiler of 779 hp. rated capacity, the active water heating surface, upon which the rating is based, being 7787 sq. ft. which amounts to a little less than 4 sq. ft. per kw. served. The boiler is set comparatively high and the Liptak double suspension arch with which the setting is fitted is built well up over the grate so that

the combustion space thus made available is ample to permit of efficient operation at considerable overloads.

Coal is burned on a motor-driven Coxe chain grate stoker, equipped for forced draft operation, which has an effective area of about 144 sq. ft. This gives a ratio of heating surface to grate area of about 54 to 1. The combustion space has a volume of approximately 1200 cu. ft. or about 8⅓ cu. ft. per sq. ft. of grate surface. At rated capacity the fuel consumption is about 3600 lb. per hr. which amounts to about 25 lb. per sq. ft. of grate surface per hour and about 3 lb. per cu. ft. of furnace volume per hour. Such proportions allow for a considerable increase in capacity without any material effect on the completeness of combustion.

Ash is carried over the end of the stoker and falls into an Allen-Sherman-Hoff cast-iron fire brick lined ash hopper which is partially filled with water. The ash is thus quenched as it falls. From this hopper the ash is dropped into a narrow gage car which is then drawn outside and up on to an ash dump on the side of the embankment, by means of a motor-driven hoist.

Baffling is of the standard three-pass Stirling type. In the second pass a B. & W. "U" tube type superheater is installed, designed to furnish 100 deg. of superheat when the boiler is operated at rating and delivering steam containing not more than about 1 per cent moisture.

FIG. 4. ONE NEW BOILER HANDLES THE INCREASED LOAD

FIG. 5. THREE UNITS HANDLED THE LOAD UNTIL THIS SPRING

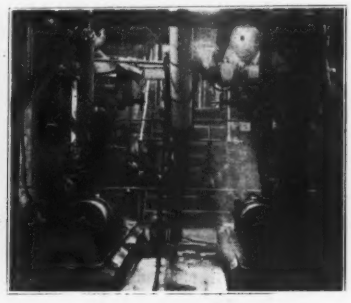


FIG. 6. TWO BOILER FEED PUMPS SUPPLY ALL FIVE BOILERS

Forced Draft Is Supplied to All Boilers

Air for combustion for all furnaces is supplied by three blowers, one Clarage and two Buffalo, located adjacent to the boiler room under the new section of the coal bunker. The one larger unit is driven by a direct connected 100-hp. 2200-v. Westinghouse motor and the two smaller each by a direct connected 50-hp., 2300-v. motor. At maximum plant capacity these units are capable of maintaining a pressure of 6 in. of water under the grates. From the fans the air is delivered to the grates through a concrete air duct running the entire length of the boiler room directly under the ring aisle.

In the new boiler installation the air is admitted to the grate through a series of wind boxes, the pressure in each of which may be independently regulated from the boiler front. Correct manipulation of the dampers in these several compartments results in zone combustion which is effective in reducing the excess air requirements. Combustion is controlled by a Craig system operating on the steam pressure.

At the time that the new equipment was installed the old 7 by 150 ft. stack was somewhat overloaded, hence when the new boiler was put in a second stack was erected. This stack, built by the Cutshall Chimney Co., is 200 ft. high, from the boiler room floor, by 10 ft. inside diameter. It serves the new boiler and two of the older 350-hp. units.

Auxiliary boiler equipment includes Diamond soot blowers, which are operated once per 8-hr. shift, G. E. flow meter, Ashcroft steam gages, Ellison differential draft gages, S—C feed water regulators, and recording flue gas, superheat and feed-water pyrometers and thermometers.

Condensate from the several condensers is delivered by individual condensate pumps to a surge tank over the boiler room. From here it is delivered by gravity to a 5000-hp. Cochrane open type feed-water heater where it is mixed with the necessary make up taken from the creek at an average summer temperature of about 80 deg. F. and heated by the exhaust from the various steam-driven auxiliaries to a temperature of from 150 to 200 deg. F. From this heater the water is fed to the boilers by two Dean duplex, 10 by 6 by 12-in. pumps.

From the boiler steam is taken off through an 8-in. lead to the main header, in which the sectionalizing valve between the old and the new equipment is ordinarily kept closed, thence, by as direct a route as possible, to the turbine. The piping is Crane fitted throughout.

Acceptance tests on the new equipment, including the boiler, superheater, turbo-generator, condenser and all auxiliaries were most interesting and are worthy of some note. They were conducted by Prof. G. A. Young, head of the school of Mechanical Engineering of Purdue University, assisted by members of the senior classes in mechanical and electrical engineering, 19 of whom participated.

In carrying out these tests it was agreed by all parties concerned that actual operating conditions and methods were to be adhered to, that no artificial conditions were to be imposed to create special test performance. Results were to be indicative of normal operation. One exception was made in loading the unit for a half-day period to as great an extent as possible to obtain some idea of the maximum load characteristics. The method of testing was that proposed by the Power Test Code of the American Society of Mechanical Engineers.

Load characteristics, as reflected in the load, power and capacity factors, have, of course, a decided effect on operating results, hence should be known if a correct appreciation of performance is to be obtained.

Summary of Significant Test Results

Boiler Tests

1.	Date of test	April 14, 15, 16, 1924
2.	Duration, hr.	48
3.	Coal used	1½-in. Illinois Screenings
	Analysis, as fired, per cent:	
	Fixed carbon	32.4
	Volatile combustible	37.3
	Moisture	14.4
	Ash	15.9
	Heating value, B.t.u. per lb.	9910.
4.	Grate surface, sq. ft.	144
5.	Water heating surface, sq. ft.	7787
6.	Steam pressure by gage, lb. per sq. in.	182
7.	Temperature of feed water, deg. F.	150
8.	Temperature of steam, deg. F.	467
	Superheat, deg. F.	88
9.	Flue gas temperature, deg. F.	520
10.	Quality of steam entering superheater, per cent	98.6
11.	Moisture in coal, per cent.	14.4
12.	Dry coal burned per hr., lb.	3190.
13.	Dry coal per sq. ft. of grate surface per hr. lb.	22.
14.	Refuse, based on dry coal, per cent.	15.7
	Combustible in refuse, per cent.	7.7
15.	Actual evaporation, lb. per hr.	25,880.
16.	Equivalent evaporation, from and at 212 deg. F., lb. per hr.	28,890.
17.	Equivalent evaporation per sq. ft. of heating surface, lb. per hr.	3.71
18.	Rated boiler capacity from and at 212 deg. F., lb. per hr.	26,875.
19.	Rated boiler capacity, hp.	779.
20.	Capacity developed, hp.	837
21.	Rating developed, per cent.	108
22.	Actual evaporation per lb. of coal as fired, lb.	7.09
23.	Equivalent evaporation from and at 212 deg. F. per lb. of dry coal, lb.	9.12
24.	Equivalent evaporation per lb. of combustible, lb.	10.8
25.	Efficiency of boiler, furnace and grate, per cent	76.2
26.	Flue gas analysis:	
	Condition of stack	Clear
	Per cent carbon dioxide	12.6
	Oxygen	6.1
	Carbon monoxide	0.3

Turbine, Generator and Condenser Test

1.	Steam pressure near throttle, lb. per sq. in. gage	179.
2.	Temperature of steam near throttle, deg. F.	467.
3.	Superheat, deg. F.	88.
4.	Pressure in first stage, lb. per sq. in.	85.6
5.	Exhaust pressure, lb. per sq. in abs.	0.75
6.	Vacuum, in. of mercury	27.6
7.	Barometric pressure, in. of mercury	29.12
8.	Temperature of exhaust, deg.	94.
9.	Temperature of cooling water entering condenser, deg. F.	61.8
10.	Temperature of cooling water leaving condenser, deg. F.	71.6
11.	Room temperature, deg. F.	63.5
12.	Steam consumption of turbine, lb. per hr.	18,210.
13.	Turbine speed, r.p.m.	3600.
14.	Brake horsepower	1538
15.	Output, kw-hr. (net)	53,426.
16.	Power factor	72.3
17.	Steam consumption of turbine, lb. per hp.-hr.	11.95
18.	Steam consumption, lb. per kw-hr.	16.70
19.	Coal burned per kw-hr. (as fired) lb.	3.35
20.	Coal burned per kw-hr. (dry) lb.	2.87
21.	Thermal efficiency of turbine, per cent.	17.97
22.	Rankine cycle efficiency between throttle and exhaust temperatures, per cent.	30.77
23.	Rankine cycle efficiency, per cent.	58.
24.	Net work output of turbine per B.t.u. consumed, ft. lb.	140.
25.	Overall plant efficiency (thermal) coal pile to switchboard, per cent.	10.6

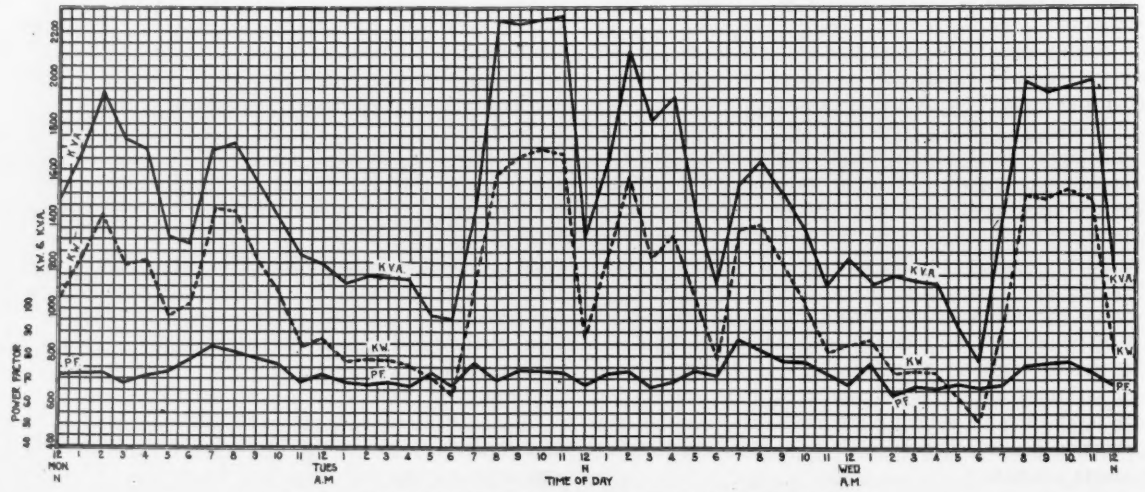


FIG. 8. DAILY LOAD CURVE SHOWS CONSIDERABLE FLUCTUATION

Under normal conditions of operation the peak load comes on at about 8:00 a. m. and continues without excessive variation until about 6:00 p. m. After this time the load consists almost entirely of street and house lighting. This gradually drops off until about midnight when only a minimum of about 500 kw. is carried early in the morning while the industrial load is coming on. From 6:00 to 8:00 there is a sharp rise to full peak load conditions.

Method of Testing

Qualitative readings were taken every 10 min. and quantitative readings, hourly. All instruments used were calibrated both before and after the test. Water was measured volumetrically in tanks calibrated for weight at the actual temperature prevailing. These tanks were placed between the heater and the feed pumps. All other connections to the pump were blanked off and all leakage from glands was caught and weighed.

Condensate from the turbine was delivered to weighing tanks on the roof from which it was discharged directly to the surge tank over the heater.

Coal was weighed in the weigh larry which had been carefully calibrated. Samples were taken at regular intervals for proximate analyses and determination of heating value.

Electrical output was measured at the station switchboard.

Tests results are summarized briefly in the accompanying tabulation.

During the first few hours of the test the coal was fired as received with the result that the percentage of combustible in the refuse was abnormally high, the average for the first 6 hr. being 21.1 per cent. After this period the coal was wetted down somewhat and this loss was materially reduced. For the seven remaining 6-hr. periods of the test the average combustible in the refuse ranged from about 4 to 13 per cent, the average for the whole 48 hr. being 7.74 per cent.

Load conditions in general are shown graphically on the chart showing the output of the unit over the 48-hr. test period. This chart shows a maximum load of 2275 kv.a. and about 1700 kw. and a minimum of 800 kv.a. and 525 kw. The power factor varied considerably reaching a maximum of 87 per cent at 7:00 p. m. when the lighting load was at a maximum and the power load, comparatively light. The minimum value reached was 64 per cent at 2:00 a. m. when the total load was practically at a minimum. This low value was caused by the large percentage of charging current required for lighting transformers at light load.

Boiler capacities during the test ranged from as low as 73 per cent of rating, at which point the efficiency was 65 per cent, to as high as 152 per cent when the efficiency was 78 per cent. Maximum overall boiler, furnace and grate efficiency was obtained at about 130 per cent of rating, when it reached a value of 85 per cent. The falling off in efficiency at ratings above about 130 per cent was probably caused by restricted flue gas passages either in the setting or in the uptake.

No load was available for testing the turbo-generator unit at its maximum capacity but the economy obtained over the existing range of load showed economies better than the guarantee. Actual and guaranteed values are shown graphically in Fig. 9. The general trend of the

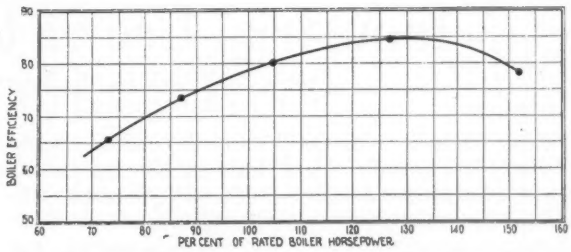


FIG. 7. MAXIMUM BOILER EFFICIENCY IS OBTAINED AT ABOUT 130 PER CENT OF RATING

actual curve would indicate that at full rating the economy would be better than the guarantee.

As an indication of the increase in plant economy the following tabulation is of interest.

	1924				
	May	June	July	Aug.	Sept.
Total kw-hr. generated	588,480	551,488	529,472	598,784	704,704
Total kw-hr. output	558,550	479,668	457,512	522,702	622,204
Tons of coal consumed	1139.6	1029.4	977.9	1012.7	1142.8
Pounds of coal per kw-hr. generated	3.88	3.7	3.69	3.38	3.22
Pounds of coal per kw-hr. output	4.32	4.29	4.27	3.87	3.67
Average load, kw.	792.	766.	712.	806.	859.
Aver. machine load factor, per cent	29.0	25.5	24.0	26.9	28.6
	1923				
Total kw-hr. generated	603,000	601,000	577,760	603,000	641,120
Tons of coal consumed	1,500	1,504	1,733	1,900	1,923
Pounds of coal per kw-hr. generated	4.97	5.00	6.00	6.30	6.00

In publishing this article we acknowledge indebtedness to H. C. Carrol, consulting engineer of Indianapolis and his associate, W. A. Breining, assisted by W. A. Edwards, to Prof. G. A. Young, head of the school of mechanical engineering of Purdue University, to H. E. Hayworth, superintendent, and to J. R. Hall, chief engineer of the Crawfordsville Electric Light and Power Plant, all of whose willing cooperation made possible its presentation.

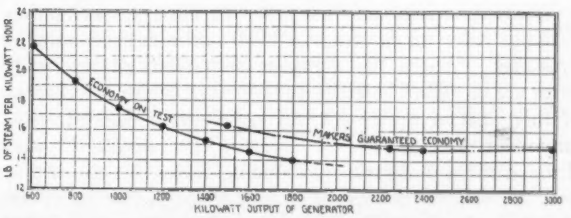


FIG. 9. TURBINE ECONOMY OVER THE RANGE TESTED IS BETTER THAN THE GUARANTEE

Industrial Use of the Bleeder Turbine

BLEEDER CAPACITY IS THE MAIN CONSIDERATION; POWER IS A BY-PRODUCT BUT EFFICIENCY IS IMPORTANT. BY CLAUDE C. BROWN

IN A GREAT many industries the manufacturing process requires the use of steam for heating, cooking or process work at a number of different pressures. The demand for steam at these various pressures may be either constant or varying and may be at pressures varying from a few ounces above atmospheric pressure to several hundred pounds. In most cases it is impracticable to maintain independent pressure systems for each pressure requirement and in many cases the problem is met by the use of steam pressure-reducing valves.

Use of reducing valves for this purpose is, however, not entirely satisfactory, due to the fact that more or less

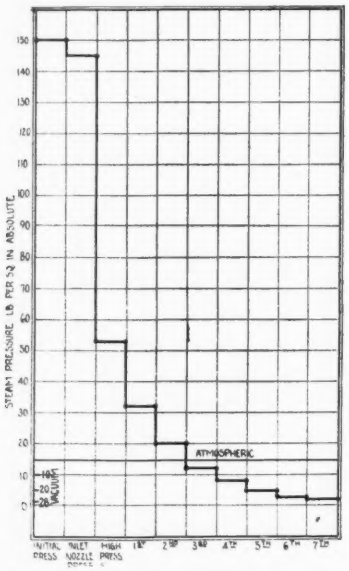


FIG. 1. PRESSURE GRADIENT THROUGH A TYPICAL BLEEDER TYPE TURBINE

difficulty is experienced in maintaining these valves in perfect working order, and also due to the fact that their use in reducing the pressure of large quantities of steam is comparatively uneconomical. In the process of pressure reduction of the steam through the action of reducing valves, the liberated energy content of the steam consequent to the reduction in pressure manifests itself in the form of heat, which tends to superheat the steam at the reduced pressure, thereby increasing its temperature and also increasing the heat losses due to radiation.

Of late years the problem of supplying steam at various pressures for manufacturing processes has been met by the increasing use of bleeder turbines or extraction turbines from which steam is bled at the desired reduced pressures. Where the demands for steam at low pressures are of sufficient magnitude to justify the installation of this class of equipment, its use shows a decided economy over the practice of securing low pressure steam through the use of pressure reducing valves, for the reason that the pressure reduction secured through the use of the bleeder turbine results in the transformation of the liberated energy content of the steam into useful electrical energy rather than into heat with its consequent increase in radiation losses.

These extraction turbines are available in sizes ranging from a capacity of one hundred to several hundred

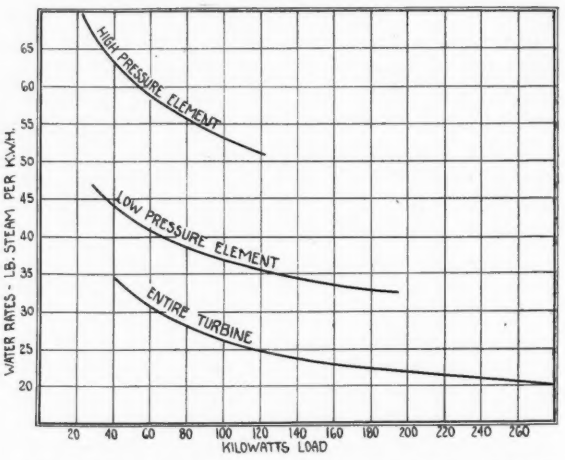


FIG. 2. WATER RATES OF THE TWO ELEMENTS AND THE ENTIRE UNIT WITH NO BLEEDING

kw. and are applicable to the purposes of many and varied industries, where electrical energy and steam at various pressures are essential to the manufacturing processes. The use of bleeder turbines in plants where they are adaptable has generally shown considerable saving and economy in the use of steam and fuel.

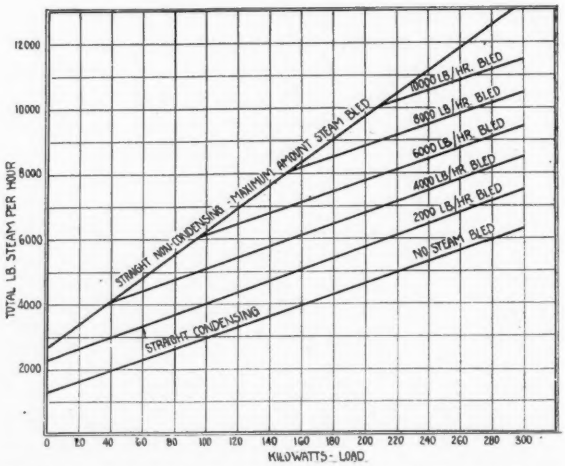


FIG. 3. TOTAL STEAM CONSUMPTION OF A BLEEDER TURBINE WITH VARIOUS AMOUNTS OF BLEEDING AT THE FIRST VELOCITY STAGE

The bleeder turbine consists essentially of a high pressure non-condensing turbine wherein the steam is expanded from a comparatively high pressure and small volume to a lower pressure and increased volume, mounted on the same shaft with a low pressure condensing turbine, with bleeder valves so located as to furnish steam at the

various reduced pressures desired. The high pressure element may consist of a two or three-row velocity wheel which discharges either all or a portion of the steam into the low pressure condensing element. The low pressure condensing element consists of a larger number of Rateau stages, those of which operate at pressures about atmospheric being adaptable to bleeding purposes. The remaining portion of the steam from this low pressure element is exhausted into the condenser.

Steam pressures in the various stages of such a unit, which consists of one two-row high-pressure velocity stage and seven low-pressure Rateau stages, are shown in Fig. 2. Figure 2 shows the water rates of a typical bleeder turbine for the high-pressure element, the low-pressure condensing element and for the combination of the two or the entire unit. Bleeder curves for straight condensing operation with no steam extraction, extractions of 2000, 4000, 6000, 8000 and 10,000 lb. per hr. and straight non-condensing operation with total extraction are shown in Fig. 3.

Steam may be bled from any stage of the turbine, above atmospheric pressure by the utilization of either manually operated or automatically controlled bleeder valves, one valve being required for each bleeding pressure. Where the demand for the bled steam is fairly constant, manually operated valves may be used but where this demand is continually varying the automatically controlled valve is essential. The bleeder pressure is maintained practically constant by the automatic action of the controlled valve, the latter being actuated by any slight change in the bleeder pressure, This valve controls the flow of steam from the receiver chamber to the low pressure condensing portion of the turbine. Probably the most flexible arrangement is obtained when the bleeding is done from a point immediately following the high-pressure or velocity stage.

In general, the requirements of a bleeder turbine are that it must at times operate as a high pressure condensing unit in which case no steam is bled from it and at other times it must operate under various conditions of steam extraction. The design of the turbine must be such that it will show high efficiency of operation under all of these conditions and that it will have nozzle areas of sufficient capacity to supply the maximum bleeding demands.

Steam Used by Surface Condenser Auxiliaries

HIGHER VACUUM IS ACCOMPANIED BY GREATER POWER DEMAND FOR DRIVING AUXILIARIES. BY JOHN D. MORGAN

DEVELOPMENT of the turbine has brought with it the gradual development of the surface condenser. In days past the surface condenser consisted of a box with brass tubes placed in it. This box had one or two water passes. Today, however, the surface condenser is a scientifically designed piece of power plant equipment, with a shape that tends to provide the maximum amount of surface consistent with sufficient steam velocities to cut out the dead air sections or tubes and by so doing it brings into action all the condensing surface.

By its favorable design, construction and operation features, the surface condenser has made possible the use of high vacuum consequently more efficient turbines are available.

Obtaining and maintaining high vacuum have also brought along the question of the amount of power that can economically be expended in the operation of the condenser auxiliaries and especially where the auxiliaries are steam driven.

Lately there has been considerable comment on the use of steam driven auxiliaries in the modern central station. This is largely due to the auxiliary steam consumption of the average central station which uses steam driven auxiliaries, being from 13 to 16 per cent of the total steam consumption of the plant. There is no question that when the utilization factor of the plant is 0.4 or less the steam consumption of the steam driven auxiliaries is quite a serious percentage of the useful steam consumption.

It has often occurred at various engineering meetings that someone would say "that so long as the exhaust steam from the auxiliaries was not escaping to the atmosphere the steam consumption of the auxiliaries was not a factor in the economical operation of the central station, for all the heat units in the exhaust steam were being recovered in the form of increased feed-water temperature." However, this theory due to the other more economical methods of obtaining a suitable feed-water temperature from other sources has vanished and all the progressive engineers of the day are concentrating on the problem of the proper method of auxiliary drive for the particular station.

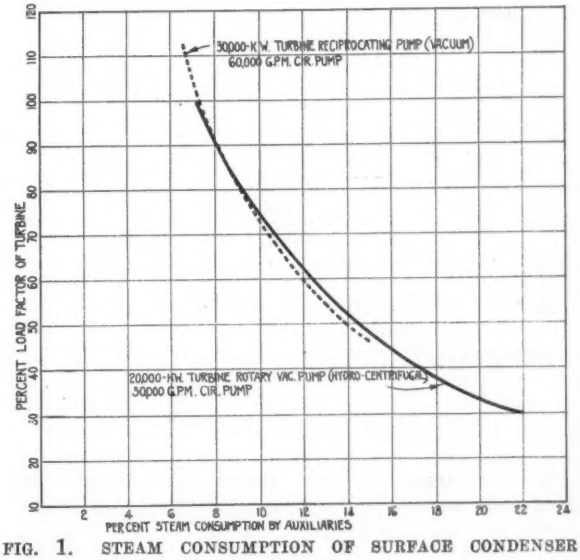

30000-K.W. TURBINE RECIPROCATING PUMP (VACUUM)
60,000 G.P.M. CIR. PUMP
20000-KW. TURBINE ROTARY VAC. PUMP (HYDRO-CENTRIFUGAL)
50000 G.P.M. CIR. PUMP
PERCENT LOAD FACTOR OF TURBINE
PERCENT STEAM CONSUMPTION BY AUXILIARIES

FIG. 1. STEAM CONSUMPTION OF SURFACE CONDENSER AUXILIARIES

To illustrate the magnitude of the steam consumed by the steam driven auxiliaries of two large surface condensers operating with steam from turbines, Fig. 1 is given. From this chart it will be observed that for surface condensers for turbines from 20 to 30,000 kw. capacity that the steam consumed by the condenser auxiliaries ranges from 7 per cent at full load to 14 per cent at half loads and with a still greater percentage at lower loads.

Auxiliaries for the modern surface condensing plant consist of the following:

Circulating pump, driven by a steam turbine or motor through a suitable gear reduction.

Vacuum pump, reciprocating or rotary displacement type driven by steam turbine or steam engine; or the

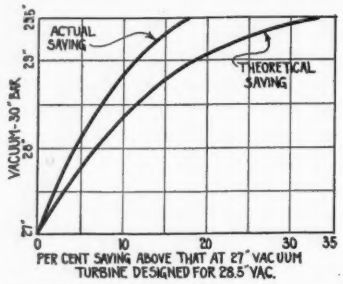


FIG. 2. SAVING EFFECTED BY INCREASED VACUUM

hydro-centrifugal or ejector type driven mainly by motor or steam turbine, no gear reduction.

The Auxiliary Steam Consumption of Surface Condensing Plants

Hot well or condensate pump, centrifugal, either motor or turbine driven, no gear reduction.

Of late there has been considerable development work done on the steam ejector air pump. The consumption of energy of the steam ejector air pump is less than that of the water ejector but owing to the high velocity of flow the construction of a satisfactory apparatus is more difficult and many nozzle phenomena have yet to be solved.

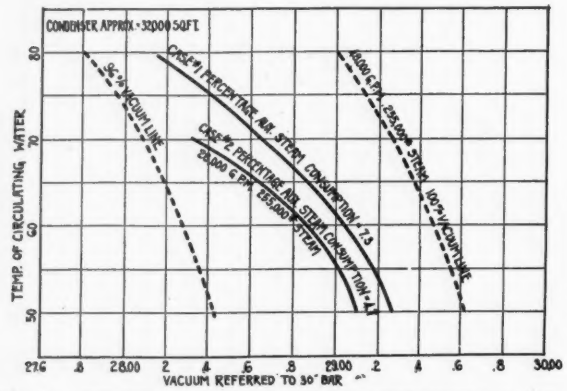


FIG. 3. EFFECT OF AMOUNT AND TEMPERATURE OF CIRCULATING WATER ON VACUUM OBTAINED

It is natural that high vacuum requires increased power consumption by the surface condenser auxiliaries, for the heat transfer rate in the condenser is a function of the velocity of the circulating or cooling water as well as the difference in temperature between the steam and the water.

The amount of condenser auxiliary power that one is justified in using depends on the ability of the main generating unit to respond to high vacuum in higher operating efficiency. To illustrate this point, Fig. 2 is given. One curve shows the theoretical saving that should result in increasing the vacuum from 27 to 29.5 in. on a turbine that was designed for a vacuum of 28.5 in. The other curve on this chart shows what a test revealed on the actual savings that the increased vacuum did effect on the turbine.

From a chart like Fig. 2 it is possible to calculate just how much power one is justified in expending to obtain higher vacuum. To illustrate further in a graphical manner, Fig. 3 is given. On this chart two curves are drawn; one shows the vacuum obtained by circulating a specific amount of water through the condenser and with a varying temperature of the inlet or circulating water this is designated on the chart as Case 1. In this instance the steam consumption of the condenser auxiliaries was 7.3 per cent of the total steam used by the main unit. In Case 2 about 60 per cent of the volume of circulating water as compared with Case 1 was used.

POWER CONSUMPTION OF SURFACE CONDENSER AUXILIARIES

Size and Type of Turbine	Lb. of steam condensed per hour	Circulating Pump Condensate Pump Capacity Consumption	Hot Well or Condensate Pump Power Consumption	Vacuum Pump Power Consumption	Total Steam Consumed by Condenser Auxiliaries	Total H.P. of Auxiliaries	Per Cent of Auxiliary Steam Consumption	Per Cent of Auxiliary Power Consumption	Possible Per Cent Saving by Using Exhaust Steam
8000 k.w. vertical	90,000	800 H.P. Eng. 12,000 G.P.M. 8000 lb. steam	10 H.P. Turbine 980 lb.	70 H.P. Hydro Cent. 2500 lb.	8480	297	9.4	4.4	4.4
8000 k.w. vertical	100,000	800 H.P. Eng. 12,000 G.P.M. 8000 lb. steam	10 H.P. Turbine 980 lb.	70 H.P. Hydro Cent. 2500 lb.	8480	297	8.4	4.4	3.6
9000 k.w. vertical	109,000	185 H.P. Tur. 20,000 G.P.M. 14600 lb. steam	25 H.P. 1850 lb.	100 H.P. Hydro Cent. 3500 lb.	10830	380	9.7	5.06	6.9
9000 k.w. vertical	126,000	240 H.P. 18000 G.P.M. 9280 lb.	20 H.P. 1760 lb.	Reciprocating 110 H.P. 3500 lb.	13690	370	10.05	5.06	6.5
9000 k.w. vertical	141,300	240 H.P. 18000 G.P.M. 9280 lb.	20 H.P. 1760 lb.	110 H.P. Rec. 3500 lb.	13690	370	9.6	5.06	6.9
9000 k.w. vertical	125,100	240 H.P. 20,000 G.P.M. 8400 lb.	20 H.P. 1760 lb.	110 H.P. Rec. 3500 lb.	13640	370	10.1	5.06	6.5
9000 k.w. vertical	130,800	240 H.P. 20,000 G.P.M. 9280 lb.	20 H.P. 1760 lb.	110 H.P. Rec. 3500 lb.	13690	370	10.4	5.06	6.5
80000 kv.a. horiz.	884,000	888 H.P. 80,000 G.P.M. 11,200 lb.	88 H.P. 1000 lb.	100 H.P. Hydro Cent. 4125 lb.	18525	480	6.3	1.67	4.1
80000 kv.a. horiz.	885,000	888 H.P. 80,000 G.P.M. 15,000 lb.	80 H.P. 1400 lb.	100 H.P. Hydro Cent. 4125 lb.	18525	646	7.25	1.82	5.0

This reduction of circulating water shows about 0.3-in. reduction in vacuum and a reduction of 2.6 per cent in the steam consumed by the auxiliaries.

In order to convey some of the actual operating figures of several old and more modern installations of surface condensers the accompanying table was prepared. This table shows all the essential facts of the installations in regard to power consumption.

From the table it will be observed that in all cases the power consumption of the surface condenser auxiliaries is of sufficient size to warrant the careful thought of the designing and constructing engineers as well as that of the operating engineer. All agree that the wisdom of having certain auxiliaries duplicated by steam standbys makes toward greater station reliability, but for the designing engineer to lay out a steam auxiliary drive system for the sole purpose of having exhaust steam to heat the feed water is placing a hindrance in the way of high operating efficiency which cannot be overcome by scientific operation.

Lehigh University at Bethlehem, Pa., has established an Institute of Research which will be in charge of the members of the faculty under the president, Charles Russ Richards. Its objects will be the training of men in research work, publication of results of investigations conducting of general research and of cooperative research, conduct of commercial tests and advisory service of research nature for special industries.

Analyzing a Case of Pitting

By F. F. Vater

IT IS true that cases of boilers pitting are frequent. It is also true that there must be a cause before you experience the effect. It is sometimes true that the best of engineers jump at conclusions, particularly where the possible cause of trouble is the quality of water used.

Not long ago a case was brought to my notice, in which the engineers came close to jumping at a conclusion. They were experiencing a case of serious pitting in boilers largely fed with condensation from surface condensers, while those boilers fed from the hot well of jet condensers were not pitted.

Believing it will be of general interest to follow my analysis of the trouble and see the commonsense of the conclusion reached, I submit my report following the investigation:

Report of Examination of Water

1. The examination was made to determine the probable cause of pitting in the boilers supplied with condensation from a surface condenser.

2. Admitting that metal oxidizes when pitting takes place, it is well to remember that either CO_2, SO_3, or Cl are much more active agents than oxygen.

3. It should be remembered that the action of CO_2 on metal is first to form the carbonate of that metal. That the carbonate of iron is unstable, breaks down into the oxide and releases CO_2 to repeat the operation.

4. It should be remembered that the action of SO_3 on iron is to form the sulphate of the metal. That iron sulphate is soluble in water and it is not to be expected due to the solubility, that much more than a trace will be found in the pits that have been scraped off the metal.

It should be remembered that the action of Cl on iron is to form the chloride of that metal. Iron in the chloride form is more soluble than in any other form and it again is not to be expected, due to the solubility that much more than a trace will be found in the pits.

6. It should be remembered that river water is comparatively soft; that it drains a large coal mining section, and that the waste water from coal mines is almost invariably distinctly acid.

7. The action of sulphuric acid wasted in a stream of water containing the bi-carbonates of lime and magnesia is first to dissociate or drive off the CO_2; the sulphur combining with the lime and magnesia as the sulphate. The CO_2 is soluble in water and to the extent of its solubility, will remain in the water.

8. It should be remembered that the maximum solubility of oxygen in cold water is but 2 grains per gallon. That at a temperature of 200 deg. F. it is but slightly soluble; that at boiler temperatures it is insoluble.

9. We have repeatedly tested the water drawn from an open heater where temperatures are carried at 200 deg. F. or higher with a result that oxygen is present in traces only, and that in no case did this oxygen pit or decompose either the tubes, drums, or headers of boilers.

10. It should be remembered that the action of either CO_2, SO_3, or Cl is to oxidize the metal, and the fact that iron oxide is present is no proof that oxygen alone caused the trouble. Our method, therefore, is *not* to determine the quantity of oxygen in the decomposed metal, but to search for traces of an oxidizing agent other than oxygen.

11. It should be remembered that the chlorides in a water, if in an unstable form, are actively corrosive. Further that the only positive method to determine whether or not the chloride was combined in an unstable form, is to find it in the condensation taken from the surface condenser.

12. Our analysis of the river water reported in grains per gallon is as follows:

Substance	Quantity
Silica	1.81
Iron oxide	.06
Calcium sulphate	.61
Calcium carbonate	.58
Magnesium sulphate	.35
Magnesium carbonate	.27
Total incrustants	3.68
Sodium chloride	.37
	4.05
CO_2	1.6
Oxygen	.902
Alkalinity	.90

13. This shows a very soft water, softer than Lake Michigan. Corrosive substances in this water are CO_2 (carbonic acid gas in solution), magnesium sulphate a very unstable salt which under boiler temperatures would dissociate into magnesium oxide and SO_3 (sulphurous acid). The latter substance would combine with the water to form sulphuric acid.

14. We have also a chloride which may or may not be in an unstable form. If in an unstable form it will show in the condensation from the surface condenser.

15. We *know*, then, that corrosives exist in the raw water of much greater oxidizing power than oxygen.

16. Our analysis of the condensation from the surface condenser in grains per gallon follows:

Substance	Quantity
Hardness	0.
Causticity	0.
Alkalinity	0.3
Oxygen	0.82
CO_2	0.05
Cl	0.4

Distilled water should be zero hardness, zero causticity, zero alkalinity. The fact that there is alkalinity is proof of tube leakage in the surface condenser.

We have in corrosives CO_2 (very small), and chlorine in a considerable amount. There is also oxygen but it is of less oxidizing power than either CO_2 or Cl.

The presence of Cl in the condensation is proof that the chloride shown as existing in the raw water is partially in an unstable form.

17. The sample of boiler blow-down we find to contain

Available SO_3 .....5.85 grains per gallon
Available Cl .....5.00 grains per gallon

The concentration of SO_3 is derived from its presence in the raw water and in the surface condenser tube leakage.

The concentration of chlorine is due to its presence in the condensation.

18. In a letter dated June 6, we were advised that in sending us the samples of pits scraped from the rear drum of one of the boilers, they selected the pits to collect as much black matter as possible. This was a mis-

take. The pits should have been scraped without *any* selection. This selection renders less valuable any determination we may make on the corrosive substance, or substance other than oxygen.

Again, the chlorides and sulphates being soluble, hence more or less washed out by the water, we should have had a much larger quantity to work with.

19. With the small quantity we had we found—

CO_2 present
Cl absent
SO_3 strongly present

We did not have enough material to make quantitative determinations.

20. We suggest that if our conclusions in the case need further confirmation, you have scraped from the boilers several ounces of pits without selection; send them to us and we will make a quantitative search for corrosives other than oxygen.

21. It is not to be supposed that the trouble is caused by large quantities of acid. The fact that the bottom drum shows the worst condition, and that the trouble is below the water line, shows us, it is caused by a slightly acid condition at times of the water. Were it wholly an oxygen corrosion it would be general.

At the temperature in your boilers it would be impossible for oxygen to stay in solution. It would be there as a gas.

22. The question might arise in your minds as to why pitting should exist in the boilers fed with condensation, while those fed with hot well water from jet condensers do not trouble, the answer is obvious. The alkalinity of the raw water is sufficient to neutralize the acids.

23. The fact that the water from the jet condenser hot well does not cause pitting is proof that oxygen is not the cause of the trouble, because there is a greater quantity of oxygen in the raw water than exists in any other sample sent us. This being true if oxygen is the cause, the pitting would be greater in those boilers fed with hot well water than in those fed with condensation.

24. Our conclusion is that oxygen has nothing whatever to do with the pitting you are experiencing. It is purely a case of too low an alkalinity in the raw water.

That the cure is simple and does not require a large softening plant with considerable investment.

25. Our conclusion further is, that the major portion of the trouble is caused by the unstable salt (magnesium sulphate) contained in the raw water, and that this condition can be positively and completely cured by automatically feeding the necessary alkali into your raw water as it is pumped. The quantity required will be so small, that it will not be necessary to provide a long time element. That there will be no operating difficulty in allowing the chemical reaction to take place in the boilers.

Boiler Room Records Turned Into Profits

ONE EXAMPLE WHERE INSTRUMENTS WERE INSTALLED BUT NOT USED. BY THEIR USE A SAVING OF $4000 PER YR. IS BEING MADE. BY HOWARD W. MORGAN

AT THE FACTORY of a cable manufacturing company in Connecticut is a boiler plant which is more or less typical of small industrial power plants. It has two hand-fired 200-hp. B. & W. water-tube boilers and one 150-hp. Heine water-tube boiler. The latter is kept as a spare and used only when one of the others is off the line for cleaning or repairs. All of the steam produced is used for process work and power is purchased. Normally the boilers are operated at from 75 to 90 per cent of rating.

Several years ago the boilers were equipped with CO_2 recorders and recording flue gas thermometers. The water fed to the boilers is metered and the feed-water temperature and the steam pressure are continuously recorded. No means are provided for weighing coal but composite samples of both the coal and refuse are made up and analyzed each week. Hence all of the necessary information is available to compute the combustion losses.

High-grade coal is always burned. The tests show an average of approximately 7 per cent ash and 14,150 B.t.u. A good price is paid for this coal and the management has a right to expect good results from it. Down to about a year ago, however, such results were not forthcoming. The operator in charge seemed unable or unwilling to be guided by the information provided by the recording instruments and persisted in the methods he had used successfully (to his mind) for the past 30 yr. The management fully appreciated his shortcomings but owing to his long faithful service would not fire him. Some nine months ago he died and was replaced by a young man, who is a practical man with no technical training but with a thirst for knowledge and a willingness to be guided by technical information. The instruments provided the information and technical guidance was available to interpret it and outline the program for improving operation.

In July, 1923, the average flue gas temperature for the month was 528 deg. F., and the average per cent of CO_2 in the flue gas was 6.2 per cent. This resulted in a stack loss of 24.2 per cent of the available heat in the coal burned. The temperature of the gas, considering the rating at which the boilers were operated, plainly indicated that the boilers were dirty. As the boilers were equipped with soot blowers which were regularly used and as it was known that the tubes had not been internally cleaned for at least 2 yr., it was practically certain that the trouble could be laid to scale. The first thing that was done, therefore, under the new regime was to take one of the B. & W. boilers off the line for cleaning. The tubes were found to be heavily scaled and the turbine cleaner was put to work.

While this boiler was off the line, a little time was spent in determining the cause of the low CO_2. The regular occurrence of peaks and valleys in the line traced by the pen on the recorder indicated too long an interval between firing periods and observation of the firing methods confirmed this. A large quantity of coal was shoveled into the front of the boilers at about 25 min. intervals. This was piled up so high that it was impossible to see over it and determine what was going on in the back of the furnace. The coal in the front was not pushed back and spread until the next coaling period.

Uptake dampers were equipped with hand controls at

the front of the boiler. The cable ended in a ring which could be looped over any one of a number of pegs, allowing the dampers to be set at a number of positions between wide open and closed. It was found that they were kept at the wide open position at all times except when the safety valve popped.

The fireman never looked at the CO_2 chart for the reason that the instrument was placed in the chief engineer's office some little distance from the boiler room. Objections raised by the fireman to changing his coaling method were easily overcome and a program of shorter intervals with less coal at each firing was adopted. About 5 min. after the coal was thrown in at the front of the furnace, it was pushed back and spread without adding fresh coal. As a low volatile coal was burned, this was found to be ample time to burn off the gas and allow the coal to coke.

Instructions were given to the fireman to adjust the dampers and keep them as nearly closed as he could and still maintain steam pressure. The chief engineer was fully instructed in the meaning of the CO_2 records and made responsible for a good average being maintained. As a mark to aim at, an average of from 10 to 12 per cent would be considered good. No hard and fast rules were laid down either as to the damper manipulation or the coaling method, except the general principle that the dampers must be regulated to keep down excess air and that the coaling must be done at shorter intervals and no holes in the fire be allowed to develop. The engineer was to watch the CO_2 record and observe the condition of the fires and the damper position at each change and watch the effect of any manipulation of either on his CO_2 line. It was up to him and the fireman together to work out the operation so that a good average would be maintained.

Gains Made After One Year of Operation

In July, 1924, the average flue gas temperature for the month was 477 deg. F., a drop of 51 deg. as compared with the same month a year previous. The boilers carried approximately 15 per cent greater load than during July, 1923. At the same time, the average CO_2 was 12.6 per cent against 6.2 per cent for the previous year. The resulting stack loss was 11.0 per cent as against 24.2 per cent for the corresponding period of the previous year.

Table Showing Heat Balance

Heat Balance Based on Coal as Fired	July,1923	July,1924
Heat absorbed by the boilers.....	59.6%	73.5%
Loss of heat up stack.....	24.2%	11.0%
Loss of heat in the refuse.....	2.4%	1.8%
Loss due to moisture in coal.....	0.3%	0.2%
Loss due to hydrogen in coal.....	3.5%	3.5%
Radiation and unaccounted for losses	10.0%	10.0%
	100.0%	100.0%

In order to see how much of a saving in coal is made by this reduction of the stack loss, we need to know what the general overall efficiency of the plant was a year ago. Coal is not weighed and the plant has not been operating long enough on the improved basis as yet to get the figures from the coal bills. Having the data necessary to figure all of the losses except the radiation and unaccounted for losses, we can, by making an assumption of the amount of these latter losses, construct a heat balance that will be pretty close to the actual results obtained—plenty close enough for our purpose of arriving at an approximate figure of the coal saved. Allowing 10 per cent in each case for the radiation and unaccounted for losses and deducting the sum of all of the losses from 10 per cent to get the heat absorbed by the boiler, the heat balances work out as shown in the accompanying table.

As the other losses with the exception of the ash loss are unpreventable and since the ash loss is small and normally subject to as much variation from month to month as is shown in these two months, the figures for the saving in coal need consider only the difference in the stack loss. The stack loss in 1923 was 24.2 per cent while in 1924 it was 11.2 per cent. The difference between these two figures is 13.2 which divided by 59.6, the heat absorbed by the boilers for July, 1923, shows that the equivalent saving was 22 per cent. This means that to develop the same amount of steam in July, 1924 that was used in July, 1923 would require 22 per cent less coal.

What has it cost to make this saving? In this case, absolutely nothing but a small amount of executive time in training the engineer in charge and checking up on the records. The cleaning of the boilers is, of course, considered a part of the general boiler maintenance. The instruments were already installed. No new equipment of any kind was purchased. Instead of the instruments being regarded as new fangled ideas, somebody dug into the records they produced and acted on the story they told and a young man—just an ordinary young practical man, who had only recently come up from the firing line—was willing to try to improve on the methods that had been in use for 30 yr. In this comparatively small plant the difference between having instruments and using instruments will be about $4000 per yr. in favor of the company.

Do This Now

DUTIES are usually the things that get put off until tomorrow. There is nothing very thrilling about a duty; it is usually a bore.

But the wise man realizes that many duties are privileges or advantages, he goes on and performs them cheerfully and is so much the better off.

The point of this is that it is a duty to pay the dollar membership dues and join the Red Cross during the annual Roll Call, November 11 to 27. Look at it this way. It is a privilege to be a part of the greatest humanitarian organization in the world. It is a satisfaction to feel, when you read in your morning paper that there is an earthquake in Japan or a flood in Ohio, that you are doing your share to relieve the consequent suffering. During the war you felt the thrill of having a part in the work. But the peacetime work, though less spectacular, just as broad and effective. Indeed, if the war brought you in direct contact with the Red Cross or, if since the war you have had firsthand experience of its work in disaster relief, relief for disabled veterans, Public Health Nursing or First Aid, you will be eager to join. You will realize then what the Red Cross has really meant to thousands, yes, to millions of sufferers in every corner of the country, and in every country in the world.

It is your duty to join. Very well. But realize too that it is a privilege and a pleasure as well, and when Thanksgiving comes around and the Roll Call is over, you won't have to say: "Well, I meant to join. I know I should. But I forgot."

Foreign Practice in Vertical Water-Tube Boilers

DESCRIPTIONS OF A NUMBER OF EUROPEAN TYPES OF VERTICAL WATER TUBE BOILERS TOGETHER WITH THEIR RELATIVE ADVANTAGES. BY F. JOHNSTONE-TAYLOR

VERTICAL water-tube boilers are being regarded with considerable favor by engineers in Europe at the present time. Simple in construction, they present several advantages and most of the difficulties formerly experienced in the construction of these boilers have been overcome.

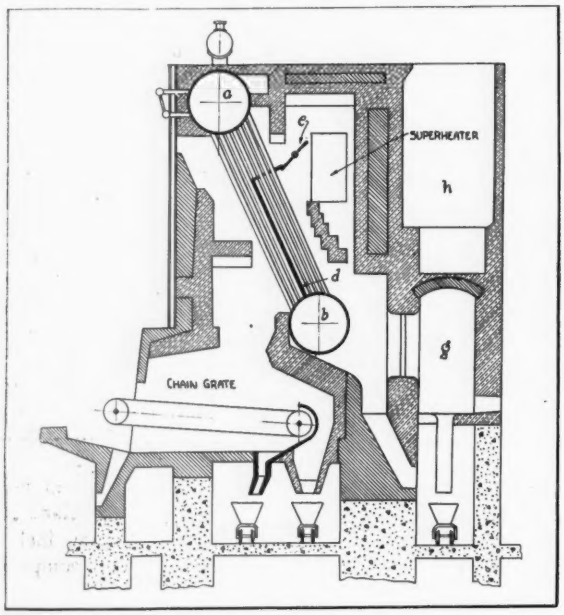


FIG. 1. CROSS SECTION THROUGH BOILER OF THE SULZER'S DESIGN

Considerable controversy has existed among power plant engineers over the relative merits of inclined and vertical tubes for water-tube boilers. Exponents of the former type claim that with them there is solid water or nearly so inside the tubes on the fire side while the steam produced inclines to the top side a condition presumed favorable to efficient circulation. In the vertical tube boiler, on the other hand, there is supposed to exist a geyser-like action by which the mixture of steam and water in the tube is maintained at a density at the side nearest the fire equal to what it is on the further side. On this score it is claimed that the inclined tube has greater durability and that the vertical tube shows no superiority in the matter of circulation, while in addition when steam is raised the lower drums that are not exposed to the fire are cold, a condition supposed to exist in the cylindrical boiler when steam is raised until the stop valves are opened.

With the vertical type of boiler there are no rigid connections and the steam and water spaces are large, while owing to the absence of tube caps, the trouble of keeping several hundred of them tight is eliminated, at the same time caps are not an essential part of all inclined tube boilers. The water tubes of the vertical-tube boiler being inserted directly into the upper and lower drums are, in modern designs, quite accessible so that insertion and removal of the tubes is a simple matter. The upright arrangement of the tubes ensures their contact with the hot gases throughout their whole length so that the effective heating surface of this type of boiler is greater than most other types of water-tube boilers. Moreover the banks of tubes, being suspended, are free to expand, thus leakage between tubes and drum is reduced to a minimum.

This upright arrangement of the tubes enables steam bubbles formed in them to rise freely to the steam drums by the shortest possible path. Although this, as stated, is considered by some to cause a geyser-like action, nevertheless it has the virtue of ensuring a brisk circulation in the whole boiler constantly maintained by the rising steam bubbles. The formation of steam pockets is thus prevented and with it a good deal of the risk of overheating and incrustation while any sludge is deposited in the lower drums. These vertical tubes are also favorably placed for the removal of soot as compared with inclined ones.

The course of the steam in these tubes being direct, a rapid circulation is induced at the front of the boiler, while the water flows downwards through the back tubes which, being subject only to the heat of the coolest gases act as economizer, feed-water heater and purifier. The feed being led into the rear headers of the boiler where it is evenly distributed, passes down the tubes and is heated

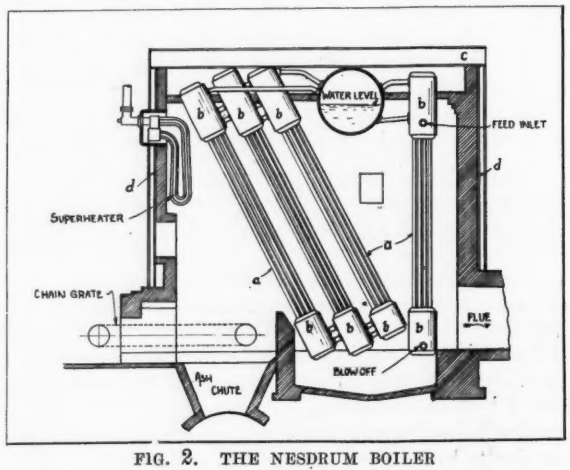


FIG. 2. THE NESDRUM BOILER

sufficiently to deposit any scale forming matter, which, in the form of mud, falls to the bottom drums as stated.

While the vertical tube boiler in its present form only dates back some 10 or 15 yr. attempts had been made sometime previously to design and build boilers of this class following the lines of small bore tube marine boilers. The difficulty met with at the time was the formation of the plates to accommodate the tubes. The Garbe tube plate was patented as far back as 1900 but was then regarded as incapable of commercial manufacture. The boiler shown in Fig. 1 of Sulzer's design embodied these Garbe plates and consists of an upper drum *a* and a lower drum *b*, 48 in. to 60 in. in diameter and connected together by straight tubes. These boilers are constructed with either single or double banks of tubes. The specially shaped Garbe plates are riveted to plain plates of nearly equal thickness by a good double butt strap joint, the buckles being large enough to allow of tubes up to 2¼ in. in diameter being inserted.

This Garbe plate is provided with stepped pressed buckles or corrugations, each buckle dimensioned for the insertion of two tubes, the cylindrical shape being retained between each pair of tubes lengthwise and crosswise. This permits of one tube being easily withdrawn at any time without disturbing the others. These special plates form the upper half of the lower drums and the lower half of the upper ones.

It will be observed that the nest of tubes is divided by a brick baffle into two unequal parts, the front portion which comes into direct contact with the fire carrying a somewhat larger number of tubes than the back portion in order to create the necessary draft section. The hot gases pass upwards along the tubes and can be diverted by damper *e*, through the superheater, afterwards passing down along the back portion of the tubes and then to the flue through economizer *h*, should one be provided. In view of the fact that with high-pressure boilers the economizer is a matter of difficulty leading to a tendency to substitute air pre-heaters for utilizing the waste heat in the flues, these air pre-heaters are well suited to use with vertical-tube boilers, bearing in mind that, as before pointed out, a portion of the tubes in a vertical-tube boiler may become, in effect, an economizer.

While Fig. 1 shows a single bank boiler, a double bank boiler is arranged much in the same way, the rear one standing vertically, while the two banks are interconnected at the upper and lower ends by large pipes in addition to a common steam receiver. Between the two banks the superheater is located, and by means of a damper the hot gases may be passed through it on their way from the first to the second or it may be cut out as required.

A British Design, the Nesdrum

This boiler, which has several special features and a moderate overall height, is shown in Fig. 2. The upright tubes, *a*, are arranged in small groups or nests and expanded into small drums, *b*. The sections are all expanded and tested at the works, the nipple tubes only being fitted on the site, an arrangement which facilitates and cheapens erection.

The drums being cylindrical and fitted with spherical ends, any stays which are likely to impede circulation and cause other troubles are done away with. These boilers are provided with straight nipple tubes for connecting the sections while the lower headers or drums are of sufficient depth to enable the nipple tubes and the main tubes to be easily inspected with the aid of an electric lamp, while any of the tubes can be easily withdrawn and replaced by drawing them through the manholes.

When cleaning boilers of this type the interior of each group of tubes can be washed through an ordinary manhole, brushes or turbine cleaners being inserted into each tube from outside the drum, enabling scaling to be done as soon as pressure is down without any loss of time. Soot removal by a steam jet can be carried out while the boiler is in operation, soot cleaning doors being provided all round for this purpose. As will be seen from Fig. 2 the pressure parts are suspended from overhead joists, *c*, on a steel structure, *d*, allowing plenty of freedom for expansion and contraction, while the entire absence of flat stayed surfaces is conducive to the safe carrying of high pressures.

This is shown in Fig. 3 and consists of an upper steam drum, *a*, and a lower mud drum, *b*, connected by a double row of tubes, *c*, which are expanded at their ends. The steam drum is of somewhat larger diameter than the mud drum. The holes in both drums are accurately machined to receive the tubes which are vertical and straight. There are only two rows of tubes and in plan they are arranged in an extended W form and are $2\frac{3}{16}$ in. or $2\frac{3}{8}$ in. in diameter according to the size of the boiler. At the longitudinal center line of the boiler, however, are located a certain number of 4-in. tubes inside of which, supported by three point supports, are smaller concentric tubes, bell

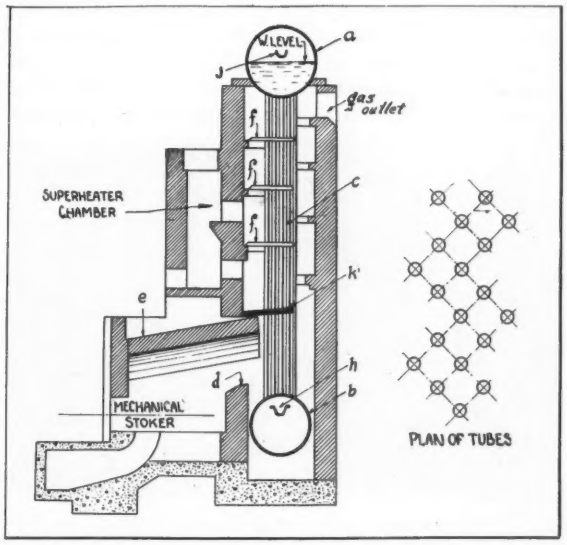


FIG. 3. A FRENCH TYPE OF VERTICAL WATER TUBE BOILER

mouthed at the top and projecting into the bottom drum so as nearly to touch deflector, *h*, therein. The feed enters the top drum and passes into tray, *j*, from which it overflows. This water, passing through the circulating tubes which are inside the larger evaporating tubes, strikes deflector, *h*, where its velocity is reduced before it returns up the evaporating tubes.

The circulating tubes being surrounded by water no steam is produced in them, but they have a rapid velocity which is regarded as of material assistance in preventing deposit, while the sudden reduction of velocity by the deflector throws down most of the scaling matter in suspension. In the return path for the water to the steam drum through the evaporating tubes the ratio of the volume of steam to water is approximately one to eight and as the volume of steam in these tubes is comparatively small, there is little risk of the tubes being damaged even under considerable forcing.

It will be seen that the grate is placed on a level with the lower drum which is shielded from the heat radiated by the fuel bed and from the hot gases by firebrick wall, *d*.

At suitable intervals above this arch are cast-iron baffles, *f*, similarly shaped and the hot gases are made to zigzag their way through the tubes to the gas outlet. The furnace, it will be observed, is of a reverberatory type rendered necessary when using bituminous fuels in order to maintain the fuel bed at a sufficiently high temperature to ignite the volatile hydro-carbon gases. This boiler, it might be noted, in common with other vertical-tube boilers is well suited to burning uncleaned blast furnace gas.

Wilson Dam at Muscle Shoals Is Going Forward

LARGEST PIECE OF CONCRETE WORK TO BE COMPLETED NEXT YEAR. USE TO BE MADE OF POWER NOT YET DECIDED. CONGRESS MUST ACT BEFORE IT CAN BE UTILIZED FOR MANUFACTURING OR FOR TRANSMISSION. BY W. B. WEST

BECAUSE OF its size, the connection of the Government with it, Mr. Ford's offer and the political campaigning for and against acceptance of that offer, the Muscle Shoals development is probably the best advertised water power project that has ever been attempted. Attempted seems to be the right word at present, for nobody seems to be able to solve the riddle as to what is to be done with the power when the plant is completed, yet, unless some solution is found, we shall have a power plant on our hands which will be as useless as the war-time fleet of wooden ships which are now being burned or left to rot at anchorage.

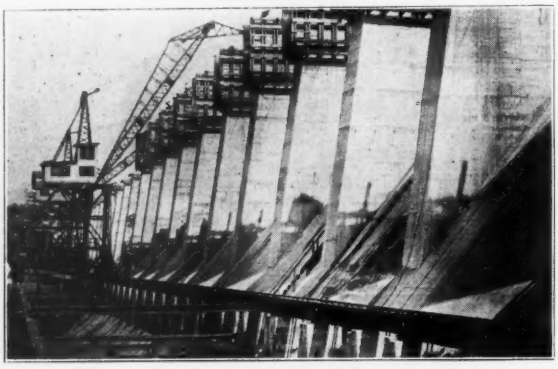


FIG. 1. DOWNSTREAM SIDE OF SPILLWAY SECTION OF WILSON DAM SHOWS MAGNITUDE OF THE WORK AND DIFFICULTY OF CONSTRUCTION

First let us have a hasty glance at what the project is and how it now stands. In the view on the contents page is shown something of the work in its present condition. This spillway section is 3050 ft. long with a lock section at the far end 200 ft. long. To the right of the view is the power house section, not completed, 1250 ft. long, a total length of 4500 ft. From the river bed to the crest of the spillway is 95 ft. with base 105 ft. thick. The power house will be 160 ft. wide and 134 ft. high, housing 18 turbine units, four of 30,000 hp. each and fourteen of 35,000 hp. each, a total of 600,000 hp. Total concrete used and to be used will be 1,291,400 cu. yd. or enough to build 735 mi. of concrete road 18 ft. wide and 6 in. thick.

Illustrations give an idea of the progress of the work. The spillway is well along; draft cones for four units are completed and forms are in place for three more; concrete scroll cases and draft tubes are under construction but the power house building proper is not far advanced.

Experience and tests have shown that the best concrete for the rather complicated forms is either five sacks of cement to 25 cu. ft. of gravel and 9.9 cu. ft. of sand, giving a 1:2:5 mix, or six sacks of cement to the same amount of gravel and sand, giving a 1:1.4:4.2 mix. In either case, 25 lb. of hydrated lime is added to each batch

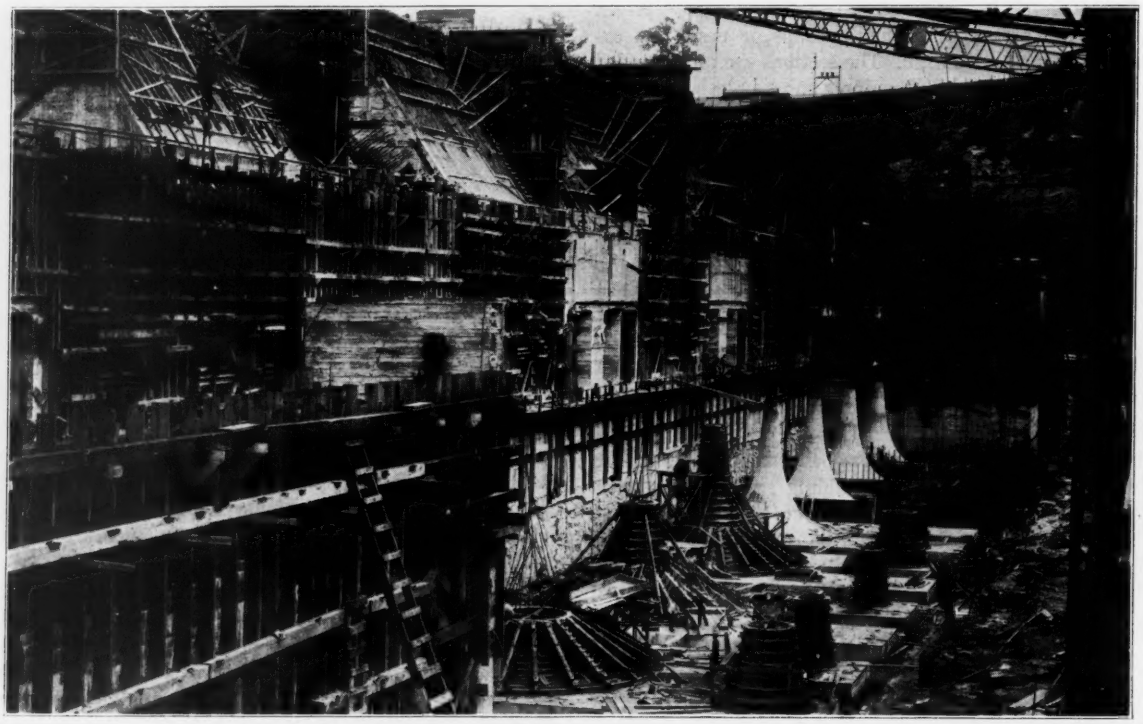


FIG. 2. DRAFT TUBE CONES ARE USED TO DIRECT FLOW OF WATER AWAY FROM WHEEL WITHOUT EDDIES. INLETS TO SCROLL CASES FOR WHEELS ARE SEEN ABOVE

and gives freedom from segregation and honey-combing and a hard dense surface.

As a comparison of the volume of this dam and some other structures, the total concrete will be 1,291,400 cu. yd.; for the Assuan, Egypt dam, the volume was 1,179,000 cu. yd.; for the Kensico, N. Y. dam it was 942,000 cu. yd. and for the Keokuk, Ia. dam, 540,000 cu. yd.

Use to be made of the power has been suggested along two lines; first, the most discussed use is for the production of nitrates to be used in making fertilizer. This is an important development and a considerable amount of such nitrates could be produced but it is the opinion of those in best position to know that the output would be but a small part of the fertilizers needed by the farms of the country and would have little effect on the price of such fertilizers. The undertaking calls for rather a large investment in chemical plant with the prospect that radical improvements in the process of nitrogen fixation from the air might render the plant obsolete within a few years. Second, it has been proposed to establish a manufacturing center at the Shoals and endeavor to attract industries there or to sell the power for transmission to industrial centers already established.

In either case it would put the Government into the field of competing with private industry, either as a developer of an industrial center or as a central station owner. Experience of Government operation of business —the railroads and ships—does not give reason for enthusiasm for such a project. Furthermore, the act authorizing the construction of the Muscle Shoals development distinctly states that it is to be for war work and may not be used for commercial manufacturing purposes or for the generation of current for sale in competition with privately owned plants. This provision would have to be nullified by congressional act before such disposition could be made of the plant.

As the matter stands now, we are going ahead to finish the work, which must be done unless all that has already been put in is to be a total loss. We shall have an investment of many millions of dollars and a plant ready to utilize 600,000 hp. which is now going to waste. But the power will have "no place to go." President Coolidge is asking for a committee of men who are familiar with power developments to investigate and report as to the best plan of procedure. That seems a common sense first step—to find out what is best to do and how it can be done. The silliest possible course is to go ahead and complete the plant, then sit around and wait for an inspiration as to what to do next, or for somebody to come along and make an offer to take it off our hands. Every indication is that it will be a splendid and successful piece of engineering. It remains to match that success in the handling of the operation and disposal of the power.

Features of Airless Injection Oil Engines---III*

COMBINATION STEAM AND OIL ENGINE, BUILT IN ENGLAND, ILLUSTRATES USE OF DIFFERENTIAL FUEL VALVES. BY H. F. BIRNIE AND R. C. BAUMANN

ON THE engines described so far, the spray nozzles had lightly loaded check valves which open practically as soon as the fuel pump plunger begins to deliver fuel oil. If one draws up a chart showing on the abscissa the degrees of crankshaft rotation and on the ordinate the displacement of the fuel pump plunger and its velocity, one would find for cam-driven plungers (with continuous contact) two curves similar to Fig. 1. For plungers driven by eccentrics and with large clearance space the curves are on the order of those in Fig. 2.

In Fig. 1 the oil pressure in the fuel line is built up gradually, whereas Fig. 2 shows the pump plunger starts in with a high velocity due to the eccentric moving rapidly as it strikes the plunger. If one tries out, in the open air, an automatic spray nozzle with light spring tension on the check valve, by moving the pump plunger by hand, it will be found that the fuel requires a certain pressure before it breaks up in fine particles. When the plunger moves slowly the fuel oil comes out of the sprayer as a fine stream but breaks up progressively into a mist as the speed is increased and the pressure at the nozzle tip is higher. It is evident that if the movement of the plunger is stopped gradually instead of suddenly, the oil mist will degenerate from a fine mist into a divided and finally into a solid stream of fuel before the check valve closes. In other words, in order to obtain a well-divided spray, it is necessary to build up rapidly the pressure in the fuel oil line and to release it suddenly so as to prevent the formation of a solid stream of oil.

*Part I appeared in the July 15 issue and part II in the Oct. 15 issue.

It seems further logical to admit that the atomization of the spray depends upon the pressure difference in the fuel line and in the combustion chamber. In the atmosphere, the spray can be set afire, in contact with a lighted

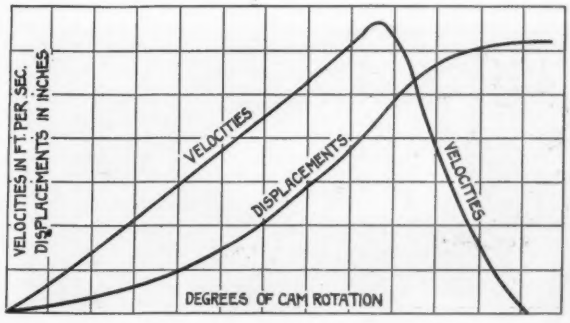


FIG. 1. PLUNGER VELOCITY AND DISPLACEMENT DIAGRAM FOR A CAM DRIVEN FUEL PUMP

candle, if it is well enough atomized, i. e., when the fuel pump plunger moves fast enough to build up a high pressure. Figure 3 shows such a burning spray. It will be noticed that the flame does not begin right at the nozzle tip on account of the extreme velocity of the oil particles at that point and because the spray is so "packed" that there is not enough air available for its combustion. How these conditions are in the cylinder can only be surmised but there is a probability that the observations made in the open air will permit certain conclusions to be drawn as to how the fuel spray behaves in the engine. For ex-

ample Fig. 3 shows that the fuel oil begins to burn only at a certain distance from the nozzle and that further the flame at the point of ignition is broad and cannot be mistaken with the core formed by the beginning of the spray.

Experiments made in Germany on sprays in an air tank under air pressures of 14 to 140 lb. have brought similar conclusions. With a nozzle opening of .016 in. in diameter

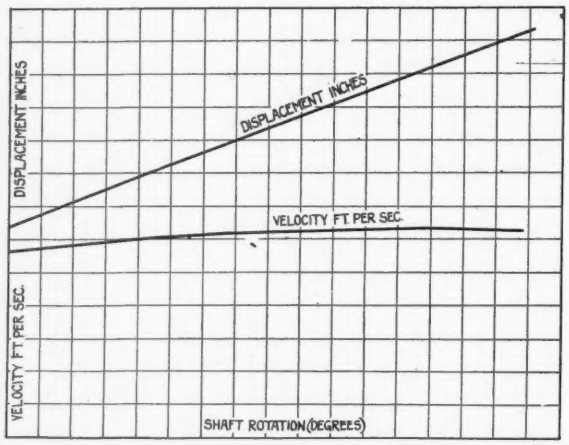


FIG. 2. PLUNGER VELOCITY AND DISPLACEMENT DIAGRAM FOR AN ECCENTRIC DRIVEN FUEL PUMP

and .040 in. in length the pressure in the fuel line was kept at 850 lb. It was then found that the liquid (in this case gas-oil) kept solidly together in a single jet up to about 4 in. from the nozzle tip. Then it dispersed rather suddenly (though less than when spraying water) and at 12 in. distance the dispersion was complete, independent of the pressure in the air tank.

So far as the design of the combustion chamber is concerned, it seems thus that it is good policy to keep it narrow near the spray tips so as to keep all the air where it

FIG. 3. SPRAY DOES NOT BEGIN TO BURN AT NOZZLE TIP DUE TO OIL VELOCITY AND DENSITY OF SPRAY

will be necessary for combustion. Hence the conical shape of some designs. In practice, also, the fuel cams have a quick enough raise to prevent the formation of a coarse fuel spray. For four-cycle engines running at 300 r.p.m. with an injection period of about 30 deg. (measured on the engine flywheel) the fuel pressure is raised from atmosphere to, let us say, 2000 lb. in about 1/10 of a second. As soon as the bypass valve is opened, this pressure is relieved suddenly and the raise and relief of this pressure occur so quickly that it prevents the fuel spray from degenerating into a stream.

Another solution adopted in trying to obtain good spraying conditions is the so-called differential nozzle. Valves of this type differ from the lightly loaded automatic fuel valves by a much heavier spring holding down a needle on a seat near the spray tip, Fig. 4. As the fuel pump plunger begins its delivery stroke, it builds up the pressure in the fuel compartment C until this pressure acting on the ring space A is sufficient to counteract the downward push of the spring. According to Dr. Sheperd a differential valve should be calculated in the following way:

Referring to Fig. 4 we see that the force P, tending to lift the valve against the spring is equal to the annular surface between the diameters d_2 and d_1 times the pressure p, prevailing in the oil chamber C.

$$P_1 = \frac{3.1416}{4} \times (d_2^2 - d_1^2) \times p_1$$

To P_1 must be added the force P_2 which acts upwards from the seat (due to the oil film on the seat) which equals

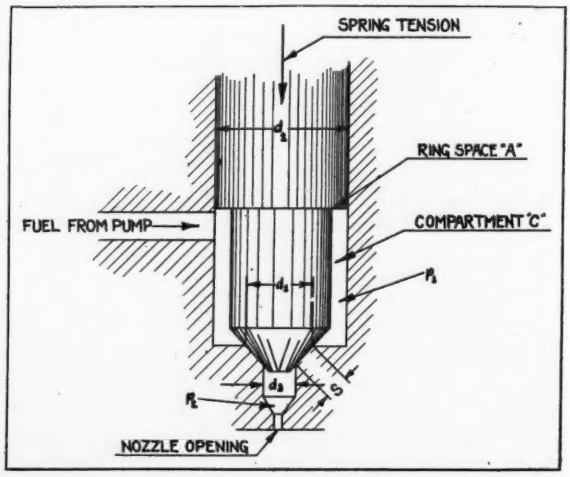


FIG. 4. DIFFERENTIAL NOZZLE SHOWING DIMENSIONS WHICH AFFECT THE OPERATION OF THIS TYPE OF FUEL VALVE

the surface of the seat times the mean of the pressures in the oil and the combustion chamber.

$$P_2 = \left(\frac{d_1 + d_3}{2}\right) \times 3.1416 \times s \times \left(\frac{p_1 + p_2}{2}\right)$$

Finally the compression pressure P_2 acting on the surface having d_3 as diameter gives:

$$P_3 = \frac{3.1416}{4} \times d_3^2 \times p_2$$

Thus, for force counteracting the spring tension is

$$S = P_1 + P_2 + P_3$$

As soon as the valve is open, the full oil pressure acts on the surface having d_2 as diameter and

$$\frac{P}{4} = \frac{3.1416}{4} \times d_2^2 \times p_1$$

Example: Let

$d_1 = .375$ in. $d_2 = .5$ in. $d_3 = .125$ in. $s = .177$ in.

$p_1 = 3500$ lb. = opening pressure

$p_2 = 400$ lb. = compression pressure

Then:

$$p_1 = \frac{3.1416}{4} \times .236 \times 3500 = 300 \text{ lb.}$$

$$p_2 = \frac{.125+.375}{2} \times 3.1416 \times .177 \times \frac{3500+400}{2} = 271 \text{ lb.}$$

$$p_3 = \frac{3.1416}{4} \times .125^2 \times 400 = 4.9 \text{ lb.}$$

$$S = 575.9 \text{ lb.}$$

S = 575.9 lb. being the required spring tension to have the valve open at 3500 lb. pressure in the fuel line.

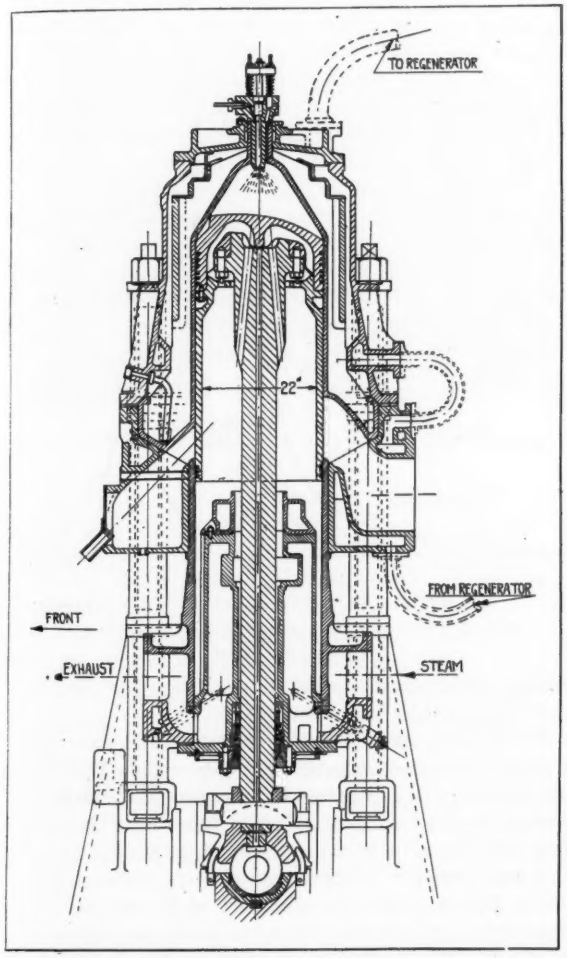


FIG. 5. SCOTT-STILL ENGINE IS DOUBLE-ACTING, USING OIL COMBUSTION ON ONE SIDE OF PISTON AND STEAM ON THE OTHER

When the valve is lifted off its seat the pressure in the chamber C acts practically on the whole diameter of the needle. With a spring tension of 575.9 lb. we thus find

$$575.9 = \frac{3.1416}{4} \times d_2^2 \times p_c$$

The closing pressure

$$p_c = \frac{575.9}{\frac{3.1416}{4} \times d_2^2} = 2930 \text{ lb.}$$

In other words as soon as the oil pressure in the fuel chamber C drops to 2930 lb. the valve closes. This figure is below the actual value; the fuel needle lift being limited to about .050 in., the pressures acting on it from the annular space around the seat and on the surface having d as diameter are below p_1 on account of the pressure loss due to the flow.

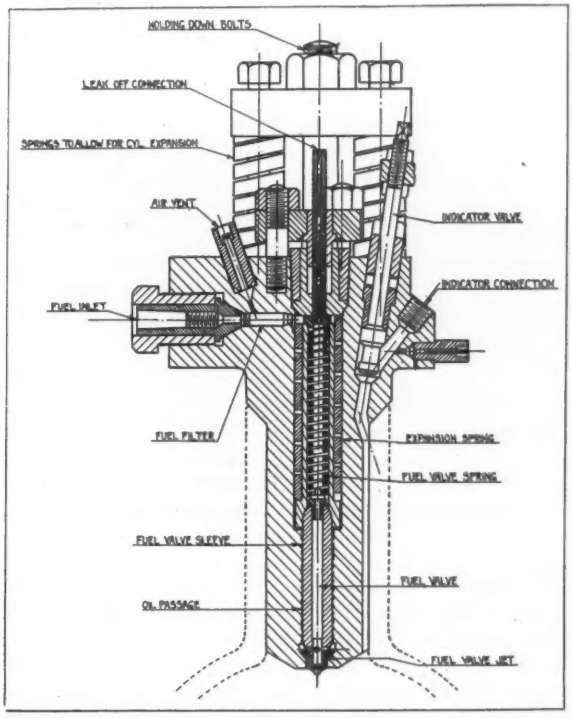


FIG. 6. FUEL VALVE OF THE SCOTT-STILL ENGINE

One of the firms using fuel valves of the differential type is the Scott's Shipbuilding and Engineering Co. in Greenock, Scotland. Their Still engine uses airless injection and also generates steam with the heat of exhaust gases, which is used in the lower part of the cylinder. The Scott-Still Diesel is, in other words, a double acting, two-cycle engine using fuel injection on the top side of the piston and steam on its bottom side.

Figure 5 shows a sectional end view. The location of the fuel valve is on top of the cylinder and it will be noticed that it acts as safety valve closing the upper end of the combustion chamber.

Figure 6 shows an enlarged view of the fuel valve. The figure is self-explanatory. The fuel valve spring is contained in a sleeve. The combustible which is led outside of the fuel valve sleeve is, in case the needle leaks, led back through the valve spring sleeve to the oil tank. It will be noticed that there is a filter at the fuel inlet and that the valve sleeve as well as the whole valve itself is held down by heavy springs. This allows for any expansion which might occur and permits the pieces to adjust themselves. The three heavy coils which hold down the valves are bolted to the cylinder cover and the fuel valve can thus be considered to act also as a relief valve.

There is an air vent to permit to draw out any trapped air. The nozzle of the fuel valve is not a single hole, but consists of a central hole surrounded by 8 drillings at 45

deg. with the vertical. The central opening is 0.020 in. and the others 0.024 in., the total area of all the holes corresponding to a drilling of 0.0706 in. in diameter.

Previous to adopting this nozzle arrangement 60 different jets were tried out, so as to select the spray which, for the shape of the combustion chamber, would give the best atomization with sufficient penetration, and distribution.

As stated in the beginning of these articles, penetration can be gotten only at the expense of atomization. After numerous experiments the builders of the Still engine decided that:

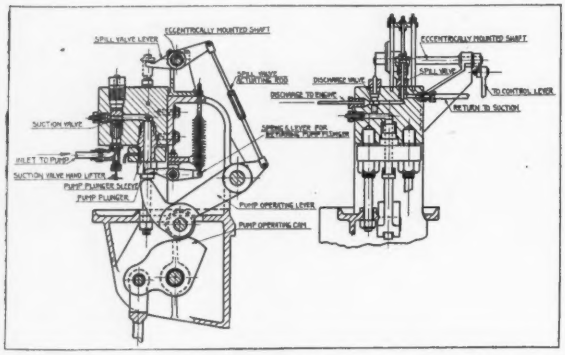


FIG. 7. ELEMENTS OF SCOTT-STILL FUEL PUMP CONSIST OF PLUNGER, SUCTION AND DISCHARGE VALVES AND BYPASS VALVE

1. Atomization depends on the relation between the size of the hole and the pressure which can be maintained by the pump. 2. Distribution depends on the number of holes at the requisite angle necessary to cover the zone of maximum air content of the cylinder. 3. Penetration depends on the diameter of the hole for a given degree of atomization. 4. The fuel pump cam shape must be such that it will give pressure and quantities to meet the combination of atomization, distribution, and penetration found most suitable from experiments.

Experiments with a single hole jet were not very satisfactory. While obtaining good atomization in the open air this spray did not give sufficient penetration and dispersion. The lowest fuel consumption was at one-half load and increased steadily at higher loads, proving that the fuel oil jet did not reach the necessary air for its combustion.

Other sprays having too great a penetration had the disadvantage of showing poor atomization and hitting the piston top, which is not a good condition as the fuel oil hitting the hot surface will tend to "crack" and give a smoky exhaust.

Figure 7 shows the fuel pump which was at first placed at the level of the cylinder head and was worked by eccentric and gear from the crankshaft. The figure seems at first a little intricate but comprises as usual a plunger, a suction and discharge valve and a bypass valve called here spill valve. This spill valve is acted upon by the fuel pump cam through levers and rod and variations of load are taken care of by rotating the eccentrically mounted shaft. At heavy loads the spill valve lever will stand lower and the injection period will last longer.

It will be noticed that the fuel injection begins always at the same moment and that the spill valve opens in the discharge line beyond the pump discharge valve. When opening, this spill valve thus relieves the fuel pressure in the line. The first location of the fuel pump had been made at the level of the cylinder head so as to shorten the pipe length. It was then transferred to the base where it was driven by cams fitted on the crankshaft. The results of the engine in fuel consumption were not affected by this change as would be expected on account of the location of the spill valve. The only sensible difference which this change in the pump position must have brought about is that, in the lower position, the "lead" of the fuel pump plunger had to be increased so as to make up for the compression of the greater oil volume in the discharge line. Difference in the quality of the atomization cannot be expected as the fuel valve opens always at the same pressure and, as the pressure is relieved each time to atmospheric, no appreciable sluggishness in its closing could occur. As seen in a previous article the delivery of a certain amount of fuel requires a longer pump plunger stroke when the oil volume between the plunger and the fuel valve increases and when the pressure in the discharge line is each time released to atmosphere.

As for the size of the pump plunger it may be mentioned that it was 1.25 in. in diameter with a lift of 1.3 in. for a rating of about 330 b.hp. per cylinder at full load. Figure 8 shows an indicator card. The compression pressure is about 290 lb. per sq. in. and the maximum burning peak is at 570 lb.

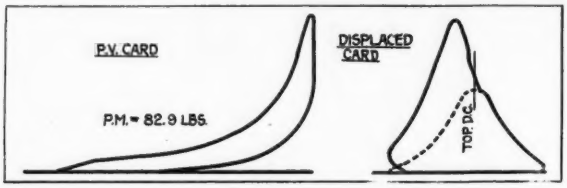


FIG. 8. COMBUSTION CARD OF SCOTT-STILL ENGINE SHOWS THE MIXED CONSTANT VOLUME AND CONSTANT PRESSURE CYCLE

It will be observed that the combustion cycle is a mixed constant volume and constant pressure cycle. Whereas a pure Diesel cycle will give at a certain fixed maximum pressure the highest mean effective pressure. The mixed cycle has the advantage, however, of requiring, for the same end pressure, a lower compression pressure giving thus a higher mechanical efficiency of the engine. The advantage gained by compressing the air to say, 550 lb. and using a perfect Diesel cycle is offset by the greater work required to bring up the higher compression. For solid injection engines, sure ignition can be obtained with 270 lb. compression.

Calculation of the indicated MEP gave about 83 lb. It should, though, be mentioned that this MEP corresponds also to the brake MEP of the Still engine as the mechanical losses are made up by work done by the generated steam on the lower side of the piston.

Figure 9 is a picture of one of the engines built by Scott's Shipbuilding and Engineering Co. The fuel pumps are disposed back and front of the engine and driven by the crankshaft. The fuel valves can be seen on top of the cylinders.

As for the design of the cam driving the fuel pump

plunger the following points should be kept in mind: 1. The first part of the cam nose should rise slowly so as to prevent heavy knocks. 2. As soon as the delivery in the combustion chamber begins the pump plunger should move with at least sufficient speed to keep up the pressure in the line.

Heavily loaded differential fuel valves are a help to the first requisite. The combustible being compressible, the beginning of the cam raise can be used to compress it to the opening pressure of the fuel valve. This compression may take place gradually. But, as soon as the spray valve is open, let us say, at 3500 lb. the speed of the

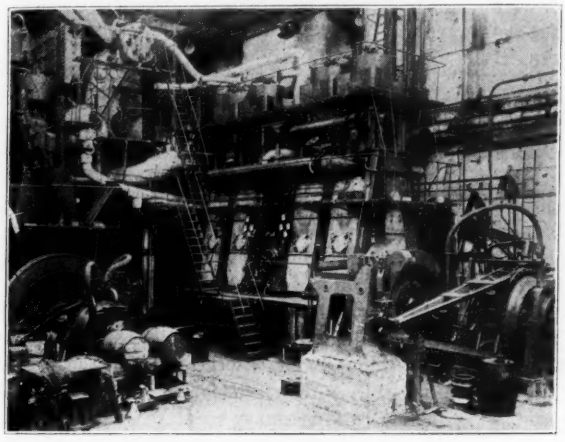


FIG. 9. A SCOTT-STILL ENGINE SET UP FOR TESTING

fuel pump plunger must be such that the valve stays open. The quantity of oil sprayed in to the cylinder depends on the size of the spray holes and the pressure at the end of the valve needle. This pressure has a minimum value which must be kept up as we must have area of pump plunger $\times$ plunger velocity = area of spray holes $\times$ velocity of oil at the holes.

Pump plunger and spray holes areas are fixed and the velocity of the fuel at the holes has a minimum value fixed by the pressure at which the fuel valve closes. Therefore, the plunger velocity at the time the spray valve is open has a fixed minimum speed. The fuel pump plunger must also deliver its maximum charge within a certain minimum crank angle of, say, 40 to 50 deg. The right contour of the cam is best determined by experiments.

During the injection period the pressure used on the Still engine ranged from 5000 to 6000 lb. The pump plunger size was, as mentioned, 1.25 in. with a total lift (only partially used) on 1.3 in. The 1.25 in. plunger was decided upon as giving the best result as probably a smaller diameter did not raise the oil pressure sufficiently and a bigger one might have caused objectionable noise between the cam and the fuel pump plunger roller by raising the pressure too rapidly, thus causing a blow effect at the beginning of the plunger raise. The lift of the needle of the fuel valve was set at .050 in.

There is unluckily no accurate data on the compressibility of fuel oils. According to Mark's handbook, the co-efficient of compressibility B is given by

$$B = \frac{1}{v_1} \times \frac{v_1 - v_2}{p_2 - p_1}$$

v_1 and p_1 being the volume and pressure at the beginning of the compression and v_2 and p_2 those at the end. For fuel oil at a temperature of 20 deg. C. and for low pressures (given in atmospheres)

$$B \times 10^6 = 55 \text{ to } 80.$$

Applied to the Still engine we might take the following values:

Pump plunger diameter = 1.25 in.
Pump plunger area = 1.23 sq. in.
Pump plunger displacement = 1.6 cu. in. for 1.3 in. stroke
Fuel pipe length $\frac{5}{16}$ in. inside diameter = 30 ft.
Volume of oil in fuel pipe = 9.9 cu. in.
Dead volume in fuel pump and fuel valve = 3. $\times$ 1.6 = 4.8 cu. in.
Maximum pressure of delivery = 6000 lb. = 422 atmosphere
Release pressure = at atmospheric pressure

This gives us:

$V_1 = 1.6 + 4.8 + 9.9 = 16.3$ cu. in.

$V_2 = V_1 - Bx\,(p_2 - p_1) \times V_1$

For $B \times 10^6 = 55$ and 80 we find:

$$V_2 = 16.3 - \frac{55 \times 422 \times 16.3}{1{,}000{,}000} = 16.3 - .378 = 15.922 \text{ cu. in.}$$

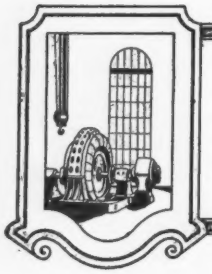
$$V_2 = 16.3 - \frac{80 \times 422 \times 16.3}{1{,}000{,}000} = 16.3 - 55 = 15.75 \text{ cu. in.}$$

If we divide these two values by the plunger area we have in one case: Stroke lost in compression $\frac{.378}{1.23} = .307$ in. or about $\frac{5}{16}$ in. and in the other case $\frac{.55}{1.23} = .447$ in. or about $\frac{7}{16}$ in.

Thus granting that the value of the coefficient B is right at these high pressures, 5/6 in. to $\frac{7}{16}$ in. of the pump plunger stroke are used in the beginning of the delivery to raise the pressure in the oil line to its proper height.

Small volumes of fuel between the pump and spray valve reduce the length of the idle stroke of the pump plunger. In the same time the spill or bypass valve can be kept small, as, in case of the Still engine only about 0.2 cu. in. volume increase are sufficient to drop the pressure from 6000 lb. to the closing pressure of 3000 lb.

No special arrangements have been made, in the Scott-Still engine to generate increased air turbulence in the combustion chamber. The scavenge air rushing in through the ports of the cylinder liner creates an appreciable air movement but there is no increase of it through restricted openings as for instance in the Price combustion chamber. Instead, the fuel nozzle was designed in such a way that its sprays had approximately the shape of the combustion chamber, all the available air being in the paths of the fuel jets. Turbulence which is a requisite for swift burning can be detrimental, when excessive, in solid injection as well as in air-injection Diesels. Some airless injection engines use combustion chambers with restricted opening to the cylinder and a great many others do not use increased turbulence to insure perfect combustion.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Operation of Converting Apparatus---IV

PARALLEL OPERATION OF ROTARIES. OBTAINING LOAD DIVISION. PROTECTIVE FEATURES. BY V. E. JOHNSON

FUNDAMENTALLY, the question of load division between d.c. machines of any type resolves itself into a problem of the proper proportioning of their respective voltages at the point of paralleling. Furthermore, they can not operate in parallel at all unless each unit inherently tends to shirk its share of an increase in the total load. In other words, the voltage of any machine, measured at the paralleling points, must droop as load is applied.

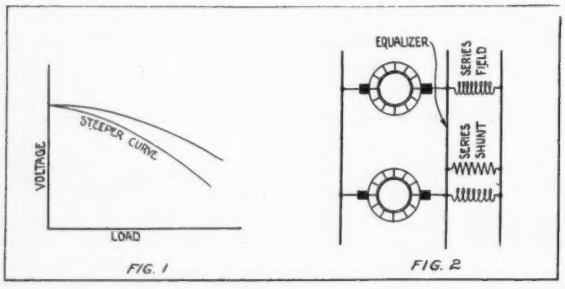


FIG. 1. CURVES SHOWING VARIATION OF VOLTAGE WITH LOAD FOR TWO GENERATORS

FIG. 2. THE CONNECTIONS FOR PARALLEL OPERATION OF COMPOUND WOUND ROTARIES IS THE SAME AS FOR D.C. GENERATORS

If the characteristic were to rise, it is plain to see that the load would increase with the voltage—the effect would be cumulative—and the combination would be unstable. This would be analogous to the condition which exists in a steam turbine when improper governor adjustment causes it to "hog" the load.

We have already seen that the paralleling of shunt wound generators is extremely simple; it is necessary to establish only two conditions, viz. proper polarity and approximately equal terminal voltages. Similarly, shunt wound rotaries are easy to run together and operate in a stable manner. This stability is affected by the amount of droop in their characteristic curves under varying loads. In Fig. 1 the steeper curve would give the most satisfactory operation, from the standpoint of ease of control of load.

Inasmuch as shunt wound rotaries, booster rotaries and induction regulator controlled rotaries, do not have any inherent compounding effect under increased load, they may be considered together. It is entirely possible for the operator to control the load division at any time by either rheostatic or regulator manipulation. With a shunt wound converter the amount of field regulation permissible is limited by the effect on the power-factor and the resultant heating. With such a machine it is, in general, possible with one rheostat setting to obtain a predetermined load division at any one point but at all other loads adjustment will be necessary. Furthermore, it is possible to obtain either unity power factor or proper load division but *not* both.

In order to obtain suitable load division between shunt wound rotaries without hand regulation after the initial rheostat setting and without deviating seriously from unity power factor, it is necessary to make special adjustments. Under ideal conditions, it should be possible to set the rheostats at the no load point on both or all machines and to leave them there permanently. So adjusted, it would be desirable for the converters automatically to assume loads in proportion to their capacities, throughout the entire operating range. Such ideal conditions are seldom possible and the "next best" would be an adjustment which would divide the loads in proportion to the machine capacities in the neighborhood of full load and to have the power factor unity at this point. This would mean that at the lower currents, the division would deviate somewhat and the power factor would be other than unity but this would not be serious, due to the fact that the rotaries would be carrying only partial load.

If the characteristics of the converters differed greatly, operation as above would be impractical. Thus, with the desired conditions at full total load, lower currents might so divide as to overheat any one of the units on account of either output, or poor power factor. It is desirable, therefore, to obtain, as nearly as possible, the following conditions:

a. The ring voltages should droop an equal amount for rotaries having the same capacity, and for machines of unequal rating an amount approximately inversely proportional to their size.

b. The d.c. voltages measured at the paralleling points should droop equal amounts for rotaries having the same capacity, and for machines of unequal ratings, an amount approximately inversely proportional to their size.

If the two foregoing conditions be fulfilled, there will be no serious heating due to deviations from unity power factor and the current division will be proportional to the machine ratings at all loads.

Assuming that the primary of the transformers which supply the rotaries are fed from the same bus and so sub-

jected to the same voltage, the conditions outlined can be obtained only by a careful proportioning of the circuits and the connected apparatus. The transformers themselves would have to have suitable regulation and the connecting leads, both a.c. and d.c., would have to be of the correct size and length. These governing features can, by careful calculation, be predetermined with considerable accuracy but the simplest method is that of "trial and error."

The machine that takes too great a share of the load, should have the resistance of its a.c. and d.c. leads increased. If there are separate adjustable reactors, the amount of reactance in the a.c. leads can be varied. At times a change in the transformer taps can be made to yield good results by shifting the "poor power factor" condition to a point on the load curve where it does no harm.

Inasmuch as booster rotaries, and those controlled by induction regulators, can have their d.c. voltage varied without in any way affecting the power factor, their operation is exceedingly simple, and is in every way comparable to that of a straight shunt d.c. generator. If they are entirely hand-operated, it is evident that considerable manipulation can be avoided by having the machines adjusted to have similar or suitable load characteristics.

Connections for the parallel operation of compound wound rotary converters are exactly the same as for d.c. generators and are shown schematically in Fig. 2. An equalizer must be used to connect the armatures in parallel ahead of the series fields. If this were omitted, the system would become unstable because any increase of load on one machine would cause its voltage to rise and, the current taken by it to become still greater. This process would be cumulative and would continue until the circuit breakers opened, or the commutators flashed over.

With the series fields connected in parallel by means of the equalizer, any increase of load on either machine would cause the series fields on both machines to increase and would tend to maintain a proper division of loads. The compounding effect of the series windings may be thought of as applying to the entire system and not to any one machine.

Looked at in another way, the armatures are paralleled independently and, as they in themselves have drooping characteristics under load, will operate in a stable manner. The series fields can be thought of as a separate excitation, varying with the entire output of all the rotaries, and proportioned among them to produce a predetermined load division.

On any one rotary converter operating alone, the amount of compounding can be adjusted by means of series shunts which divert a portion of the current from the series fields. These series shunts become of little value in dividing the load between compound wound rotaries in parallel because all of the shunts are in parallel and so affect the compounding of the entire station instead of any machine alone. This can be seen from Fig. 2.

Compounding of any one generator or rotary in the station can be reduced and the voltage curve lowered by introducing a resistance into the series circuit of that machine. This causes a greater proportion of the current to flow through the shunts and will also cause the other machines to assume a greater proportion of the total current output.

Rules for Obtaining Proper Load Division

(a.) Transformer ratios should be such that at no load and unity power factor the d.c. voltages are equal. This is easily determined by actual test. If the ratios are not correct, and the taps are not of such size as to permit accurate adjustment, all that can be done is to obtain as nearly right conditions as possible.

(b.) Resistances of the series fields and their shunts, plus the leads between them and the bus, should be inversely proportional to the capacities of the converters. This is practically equivalent to saying that the drop between the equalizer connection point, and the negative bus in Fig. 2 should be equal when the machines are carrying proportional loads. This point can be determined by adjusting the drop of each rotary separately, using a low reading voltmeter connected across from the equalizer to the bus. If the drop is too low, it can be increased by adding a few feet of cable.

(c.) Shunts should be so adjusted that the full load voltage is the same for each machine when operated separately. This is quite an easy adjustment in itself but in connection with b above may become rather a tedious job. It is, however, not essential that this adjustment be made "to a hair" and in fact many rotaries operate satisfactorily in parallel, which have quite a voltage difference when tested separately.

(d.) Resistance of the leads from the positive armature terminal to the positive bus as in Fig. 2 should be inversely proportional to the current capacities of the rotaries. This is equivalent to saying that at full load the drop in this portion of the circuit should be the same for all the machines in the station. An experimental determination of this point is easily made. If it is found that the drop is too small, a few feet of cable should be inserted.

(e.) Reactance of the various parts of the circuit should be so proportioned as to produce equal reactance drops in the various machine circuits when loads in direct ratio to the rotary ratings are carried. This is frequently an impossible criterion, as no means for making such adjustments exist. In that case, an inequality in one direction must be compensated for by one of the adjustments above.

(f.) It is seldom possible to proportion the operating conditions above so as to obtain perfect load division and unity power factor at the same time; however, it is entirely possible to make these adjustments so as to obtain satisfactory operation from a practical standpoint.

(g.) Assuming that the preceding adjustments have been made as carefully as possible, and one machine takes more than its proper share of the load, this may be remedied as follows:

1. Increase the resistance in the connecting leads between the d.c. busses and the rotary.

2. Increase the resistance of the a.c. leads—thus reducing the ring voltage under full load conditions.

3. Increase the reactance on the other machines, or decrease it on the one in question. This will make it less responsive to the effect of the series fields, and is in a way equivalent to reducing the compounding turns. Practically, this means can not always be applied as usually no means are provided for conveniently making changes in the reactance.

4. The shunt field may be set so that the load division at low loads makes the machine in question take less than

its share. Then at full loads, the additional compounding or voltage rise will cause it to take its proper proportion. This method would cause low power factor at fractional loads, but this would not cause excessive heating.

Special Instructions on Rotaries in Parallel

(a.) In the foregoing instructions it is evident that a considerable cushioning effect is introduced into the circuits by the transformers and their connecting leads. It is impossible to operate converters in parallel on both the rings and d.c. end. Under such conditions even small inequalities would cause heavy circulating currents, as there would be no limiting reactances and resistances in the circuits between the machines.

(b.) When machines open their circuit breakers under heavy overloads, care must be used in throwing them back on the line, as it often happens that their polarity becomes reversed under such conditions. If the polarity is wrong, it must be corrected in accordance with the directions given under the paragraphs on "starting up."

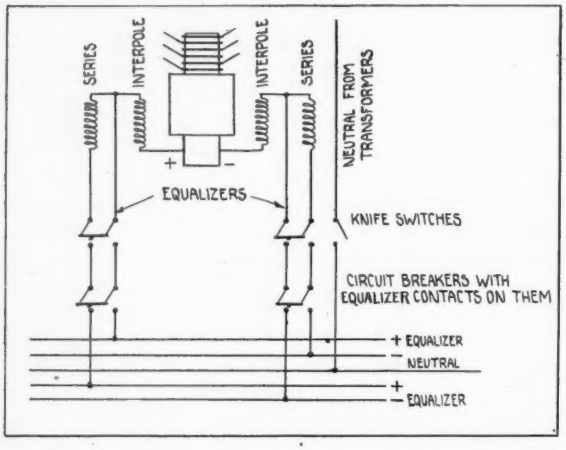


FIG. 3. CONVERTER ARRANGED TO SUPPLY THREE-WIRE CIRCUIT

(c.) If the "running" rotary is carrying a heavy load, it is safer to cut out the series fields on both it and the incoming machine, before closing the main switch. If this is not done, the surging back and forth between the machines may cause one of them to reverse its polarity and flash over. Short-circuiting switches are generally provided for this purpose.

(d.) Compound wound rotaries operating in parallel, but located in stations some distance apart need not have equalizer connections. This is due to the fact that the line drop between them is sufficient to overcome any tendency to "hogging." This is a fortunate state of affairs, for it would be practically impossible to run equalizer cables between widely scattered plants.

Protection of Rotary Converters

Rotary converters should be protected on both the a.c. and d.c. ends. It is customary to protect the a.c. end by means of an automatic oil switch connected between the primary of the transformers and the supply bus, and the d.c. end by an automatic carbon breaker between the machine terminals and the d.c. busses. The tripping of these may be accomplished by various means and devices, the selection of which is largely determined by the character of the application and the inherent properties of the machine itself.

The a.c. breaker should open under the following conditions:

(a.) Overload. On smaller machines which are compelled to assume the entire instantaneous peaks which arise, it is necessary to make this setting equal to the "swing rating of the machine" plus say 10 per cent. If the rotary is part of a system which divides up the strains due to shorts, etc., it is satisfactory to have a lower setting and to provide either a "definite time" or an "inverse time" delay.

(b.) Undervoltage. An undervoltage relay arranged to trip the a.c. breaker is essential on interpole rotaries, as a period of low voltage followed by an instantaneous rise to normal, would result in flux distortion and probably a flash over. The setting of this relay should be such as to stay closed under ordinary "dips."

(c.) Reversal of current. Isolated rotaries of medium capacity should trip out the a.c. side upon a reversal of current. Large rotaries may be connected so as to trip out the d.c. and leave the a.c. connected.

(d.) Overspeed. The overspeed device should be connected so as to trip the a.c. switch under abnormally high speeds.

The d.c. circuit breaker should open under the following conditions:

(a.) Failure of the a.c. supply at the rings. The a.c. and d.c. breakers should be so interconnected as to trip simultaneously. This is accomplished by an auxiliary switch attached to the mechanism of the oil switch so that it trips the carbon breaker.

(b.) Generally speaking—it is undesirable to trip the d.c. directly upon overloads, except on large machines. The opening of the direct current side under overload conditions is likely to result in a flash-over and should be avoided. Most rotaries will carry extremely heavy currents for a few moments without injury.

Feeders which are supplied from the d.c. bus should be protected by individual breakers arranged to operate under the proper conditions. If the feeder carries the entire output, so that its opening would throw off the entire load, it should be non-automatic. Under these conditions, the excessive load would trip the oil switch on the alternating current side and this would in turn open the machine breaker.

If on the other hand, the load is divided between a number of circuits, as would be the case in an industrial plant, it is desirable to have the individual breakers automatic. This would relieve the local conditions without entirely unloading the rotary. The individual breakers should be either instantaneous or "inverse time limit" tripping, depending upon the nature of the load.

If the a.c. supply is constant and ample, it is evident that the amount of current which may flow as the result of a short may be exceedingly great and may, during the short period of time which elapses before the overload devices have operated, rise to destructive values. It is therefore essential that this initial rush of current be limited by means of resistors of some kind, connected between the rotary and the point where the shorts are most apt to occur. In industrial service, the feeders are usually safe

from damage until the point of use is reached—so that the resistance of the leads themselves will serve as a limit.

Railway rotaries are usually located pretty close to the track, so that a broken trolley wire in front of the power house would impose a severe load. For that reason it is necessary to connect the trolley feeder to the trolley at a considerable distance from the station. This distance depends upon the size of the conductor and other local conditions but broadly speaking, the first feeder tap should not be nearer than half a mile from the bus. If it is inconvenient to interpose this length of cable, special resistors may be used.

Flashovers

There have been allusions made to flashovers a number of times. These are produced by a number of conditions—internal or external. Severe overloads followed by the tripping of the d.c. breaker, unbalancing of the magnetic flux due to disturbances in the interpolar connections, static stresses imposed by leakage or other conditions, are common causes.

If a rotary has an automatic direct-current breaker, it is important to check polarity before closing it after an interruption, as a flash-over is often followed by a reversal of polarity.

If a rotary flashes over, it should be shut down (if possible) and the brushes, commutator and rings carefully examined. Frequently little projections on the metallic parts are formed which may cause trouble if not filed off.

Operation Under Special Conditions

In a previous article on d.c. generators some consideration was given to three-wire generators. The difference between a rotary converter and a three-wire machine is essentially one of method of use, as the internal connections are largely the same. A three-wire generator will operate as a converter, the output being limited by the fact—previously mentioned—that the rings are designed for carrying small currents only.

Similarly, three-wire systems can be supplied from rotaries by connecting the neutral wire to the neutral of the transformer bank. Figures 7 and 13 on p. 1060 and 1061 respectively of the Oct. 15 issue show one scheme for obtaining a neutral. Figure 3 shows the arrangement of the converter connections. The interpoles and the compound windings are arranged in two circuits, so that compensation will be provided for unbalanced conditions.

Under special conditions it is desirable to use the rotary inverted—and to deliver alternating current from the rings. There are a number of special phenomena to be considered when this type of operation is used.

The power factor of the alternating current circuit supplied by the inverted rotary, is determined by the nature of the load itself, just as in the case of alternating current generators previously discussed. If a converter is compelled to supply lagging currents, these will demagnetize the fields and the result will be a tendency to "speed up"—just as in the case of a d.c. motor. This fluctuation in speed will tend to produce variations in frequency, which would be undesirable. Poor power factor might even result in a run-away, in which case only the functioning of the overspeed device would prevent damage.

If the a.c. end of the rotary converter (running inverted) is in parallel with other generators which stabilize the speed, the tendency to run away is minimized but the excessive heating of the tap coils is still to be considered.

At times auxiliary excitation is provided by means of exciters direct connected to the converter. This in a measure overcomes any tendency to "run away" as an increase in speed automatically results in a strengthening of the field—due to the rise in terminal voltage of the exciter.

Aside from the variation of speed which results from inverted operation, there is apt to be considerable difficulty with commutation. This is particularly the case where the rotary is floating on the line part of the time and inverts its operation at irregular intervals. Non-interpole machines operating with their brushes off neutral are sensitive in this respect, a fact which is compensated for somewhat by the fact that they are usually old types which were liberally rated.

High Voltage Phenomena

Dr. Faccioli Lectures Before an Enthusiastic Audience of 500 Engineers in Chicago

ON THE EVENING of October 6, Dr. Giuseppe Faccioli, chief electrical engineer of the General Electric Co., delivered an illustrated lecture on the subject of High Voltage Phenomena before a joint meeting of the Chicago section of the American Institute of Electrical Engineers and the Western Society of Engineers, at Chicago. This paper was highly appreciated by all who heard it, not only because of the interest of the subject itself but also because of the simple and direct manner in which it was presented.

In opening his discussion of the subject, Dr. Faccioli referred to the use of the term "Steep wave front." In explaining the significance of this term it was necessary, he said, to review briefly the principles involved in wave motion, since in nearly all high voltage work we are dealing with waves.

Now, we are all familiar with waves of various kinds, particularly waves in water. Wave motion is a manifestation of energy. Usually the greater the amount of energy associated with a body, the greater, or rather, the more pronounced will be the wave motion.

In electricity—in transmission line work we are also dealing with waves, which, although we cannot see them, are just as truly waves as are those which are set up in water.

Also, just as waves in water represent energy so do electric waves represent energy. In the case of water waves, when the energy associated with the body of water under consideration is small, the waves in that body of water will be small; when the amount of energy associated with the body of water is large, as for instance in the ocean, the waves are large.

Similarly in electricity, we have small waves and large waves, depending upon the amount of energy associated with the circuit. In the early days, when the total amount of electrical energy associated with any electrical system

was comparatively small, the waves were of little importance and were easily controlled. When, voltages gradually increased, and the amounts of power transmitted became greater, the waves began to have an increasing effect and became a source of danger to life and property. It, therefore, became necessary to protect the system against the disastrous effects of these waves.

In explaining the meaning of the term "steep wave front," Dr. Faccioli said that if such a wave (that is, one with a "steep wave front") travels along a transmission line, the potential of any point of that line rises from 0

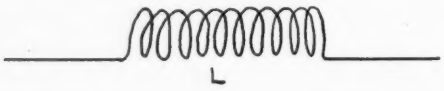


FIG. 1. SIMPLE DIAGRAM OF A LINE CONTAINING CONCENTRATED INDUCTANCE

to maximum, say 5000 v. or 10,000 as the case may be, instantly, as the wave reaches that point. Little time is required; at one instant, say just before the wave reaches it, the potential of a certain point in the line is zero; in the next instant as the wave arrives at this point, the voltage is 5000 or 10,000.

Consider, said the Doctor, a line with an inductance coil (a choke coil) in it as shown in Fig. 1. Let a wave with a steep wave front come along the wire. What happens? At a certain instant the inductance coil is at zero

FIG. 2

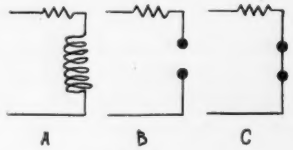


FIG. 3

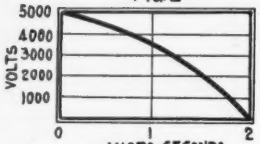


FIG. 5

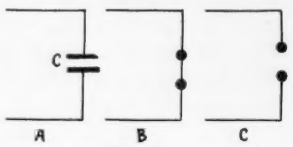


FIG 4

FIGS. 2-5. CURVES AND DIAGRAMS SHOWING EFFECTS OF INDUCTANCE AND CAPACITY

Fig. 2. Curve showing rise of voltage through inductance. Fig. 3. Diagrams showing initial open circuit effect of inductance to steep wave front. Fig. 4. Diagrams showing initial short circuit effect of a capacity. Fig. 5. Curve showing drop in voltage due to a capacity in the circuit.

voltage. Now, along comes this steep front wave and impinges upon this inductance. The steep wave may be thought of as a direct current suddenly switched on. It is moving at 186,000 mi. per sec. At a certain point just ahead of the front of this wave the potential of the wire is zero. When the wave reaches this point, the potential instantly rises to say 5000 v. and then remains at that potential. This, it is obvious, is exactly what occurs when we switch on a direct current of 5000 v.

Now what happens when such a wave impinges on the inductance? Figure 2 shows what happens.

At the instant the wave impinges on the coil, its potential is zero. As time elapses, however, the voltage gradually rises, and after two micro-seconds—two millionths of a second—it reaches the full potential of 5000 v. When the wave first impinges on the coil, the voltage is zero; therefore, the current also must be zero, since no current can flow where there is no voltage. Assume the resistance of the line to be 500 ohms. At the end of 2 micro-seconds as shown by the curve, the voltage is 5000 and the current has reached its normal value of 10 amp., since $5000 \div 500 = 10$ amp.

The question now arises, why did it take time (even though it was only 2 micro seconds) for the voltage to build up through the inductance? Why did it not instantly build up?

The reason is this; an inductance may be thought of as a reservoir for the storage of magnetic energy. When a current passes through a wire or coil, there is set up around this wire or coil a magnetic field. This field repre-

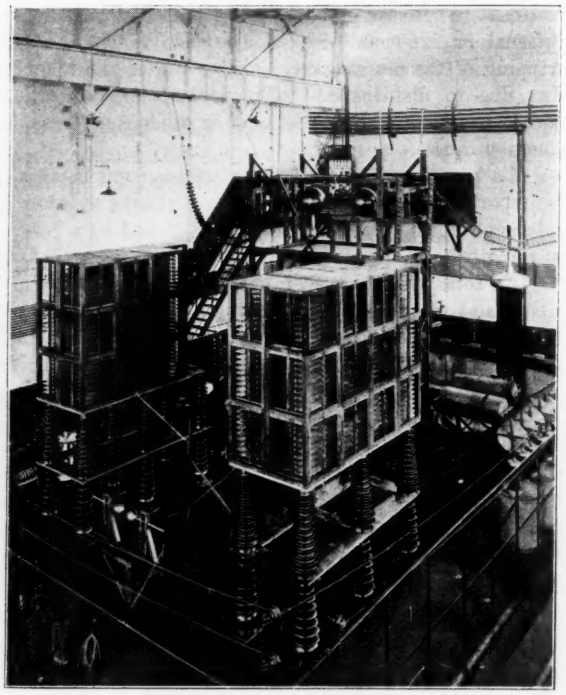


FIG. 6. THE HIGH VOLTAGE ENGINEERING LABORATORY AT THE PITTSFIELD WORKS OF THE GENERAL ELECTRIC CO.

sents energy and the energy it represents must come from the electric current itself.

In the same way, a capacity in the circuit, that is, a condenser, may be considered as a reservoir for the storage of electric energy. Thus, the two constants, inductance and capacity, are nothing more or less than reservoirs for the storage of electromagnetic and electrostatic energy.

With this explanation, it is not difficult to understand what happens when a wave with a steep wave front impinges on the inductance. As soon as the wave reaches the coil, energy in the form of a magnetic field begins to accumulate in or around the inductance. The inductance has a certain storage capacity and a certain length of time is required for this energy to accumulate in the inductance. After two micro-seconds, the magnetic field has reached its full value, and since no more energy is withdrawn from the impinging wave, the voltage and current once more become normal.

Taking this action into consideration, what is the actual effect of the inductance in a line carrying a steep

front wave? It is as though there was an open circuit in the line, at the instant the wave impinged on the inductance. The voltage at this instant has been shown to be zero, hence the current is zero. The effect, therefore, is the same as though we had an open circuit in the line as at Fig. 3b. As the voltage builds up through the coil, however, current gradually builds up and at the end of two microseconds it has reached normal value. The conditions in the line are again stable. Thus, the inductance first acts as an open circuit, and then it gradually (in 2 millionths of a second) short-circuits itself as shown in Fig. 3C.

Effect of Condenser on Steep Wave Front

Now, a condenser, explained Dr. Faccioli, acts similarly, except that its effect is just the opposite from that of an inductance.

At the instant the steep front wave impinges on the condenser shown in Fig. 4A, full voltage is impressed across the terminals and consequently, full current (10 amp.) flows. The condenser, however, is a reservoir for the storage of electrostatic energy, thus the voltage immediately begins to fall and at the end of two micro seconds it has reached zero. The current, therefore, is also zero.

It is evident, therefore, that at the instant of impingement, the condenser acts as a short circuit, allowing full

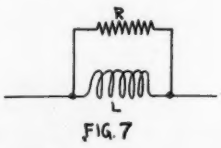


FIG. 7

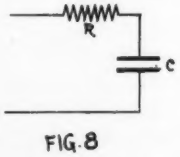


FIG. 8

FIGS. 7-8. METHODS OF CONNECTING RESISTANCES TO OVERCOME EFFECTS OF INDUCTANCE AND CAPACITY TO STEEP WAVE FRONTS

current to flow. As electrostatic energy is stored in the condenser, however, the voltage and therefore the current gradually drops and at the end of two micro seconds it is zero. The circuit, therefore is open.

So we see that an inductance and a capacity in an electric circuit have opposite effects. The inductance behaves as an open circuit which automatically short-circuits itself at the end of two microseconds, while the condenser behaves as a short circuit which at the end of two micro seconds automatically opens itself.

Now these effects are decidedly unfavorable to the operation of a transmission line and it is desirable that they be overcome if possible. When a steep front wave meets an open circuit in a line it is reflected back. In such a reflection, however, the voltage automatically doubles itself and this double voltage is extremely destructive. The important question in all this, then, is, how can we overcome the open circuit effect of the inductance and the closed circuit effect of the inductance? Easily—by simply shunting the inductance with a resistance, and by inserting a resistance in series with the capacity as shown in Figs. 7 and 8.

In one case, the resistance allows the voltage wave to pass on without suffering reflection and without allowing the inductance to open the circuit and in the other case, the series resistance overcomes the short circuit effect of the capacity.

So now, Dr. Faccioli pointed out, we have a clue. In designing our electrical machinery we must be careful not to have any concentrated inductance or capacity at any point in the line. A transformer winding, for instance, is in reality a transmission line, concentrated in small space and in circular form.

Importance of Fine Points

It is thus, by noting that it takes two millionths of a second for the current to establish itself through an inductance, and two millionths of a second for the voltage

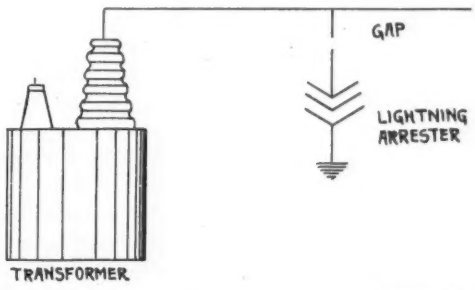


FIG. 9. DIAGRAM OF TRANSMISSION LINE PROTECTED BY LIGHTNING ARRESTER

to drop to zero with a capacity, we have discovered an important law in electric machine design. Today, we have devised a method of winding transformers in such a way that the inductance is not concentrated at any one point, thus preventing the possibility of excessive strain.

This is the point which Dr. Faccioli made especially clear—the fact that a knowledge of this two millionths of a second time interval made us able to construct better transformers.

Action of Lightning Arresters

The next part of Dr. Faccioli's lecture was devoted to a study of lightning arrester action. In the previous part of this talk it was shown that steep front waves are extremely destructive when no protection is provided against them.

Ordinary power is usually transmitted at a frequency of 60 cycles per second. This is a comparatively low frequency and the waves are 3100 mi. long. These waves are not which might be called steep front waves.

Lightning on the other hand is of an extremely high frequency as are also the transient voltages produced on transmission lines by switching operations and arcing grounds. It is against these disturbances that we have to protect our equipment. The voltage induced in a transmission line by lightning may have a frequency in the order of 6,000,000 cycles per sec. Just what this means may be made clear by the following comparison.

In 60 cycle work the current reverses 120 times per sec., or we may say the current during any quarter of a cycle increases from zero to maximum in 1/240 of a second. Putting it in another way, we may say that it takes 1/24 of a tenth of a second.

Now a lightning disturbance with a frequency of 6,000,000 cycles per sec. reverses 12,000,000 times per sec., and during a quarter of a cycle, the voltage builds up from zero to maximum in one 24 millionth of a sec., or expressing it differently for the sake of comparison, in 1/24 of a millionth of a second. Comparing this figure

with our 60-cycle current, we see that the lightning disturbance builds up a hundred thousand times as fast. It is evident then, that the lightning disturbances have extremely steep wave fronts and are therefore highly destructive.

To relieve transmission lines from such disturbances, we equip them with lightning arresters. A lightning arrester is nothing more than an arrangement which provides an easy path to the ground for the high frequency high voltage current. It allows the disturbing voltage to pass to the ground but not the power current.

It is not practicable to connect the arrester directly between the line and the ground, due to the fact that the leakage current would cause it to heat up. So it is usual to interpose a small air gap between the arrester and the line. This, Dr. Faccioli pointed out, was unfortunate but necessary.

In Fig. 9 we have a diagram of a lightning arrester separated from the line by a small needle gap. This gap

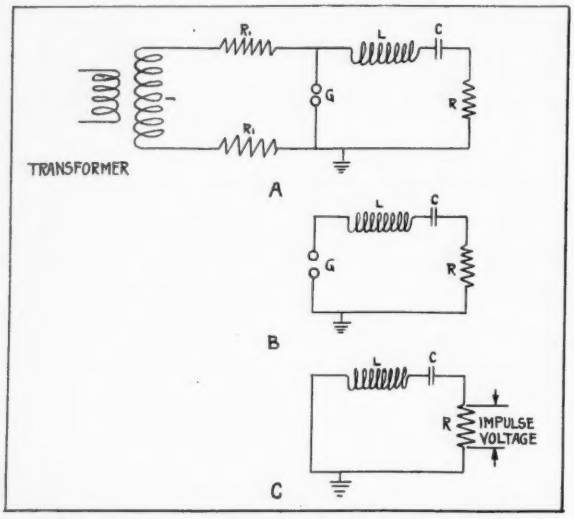


FIG. 10. DIAGRAMS ILLUSTRATING PRINCIPLE OF IMPULSE GENERATOR

is set to arc over at slightly above normal voltage; i. e., if the line voltage is, say 50,000, the gap is set for 55,000.

Let us suppose now that a lightning disturbance of steep wave front comes along the line. It strikes the needle gap and arcs over to ground, thus protecting the transformer from damage.

In practice, however, this particular kind of a gap (a needle gap) did not always protect and while the gap arced over in many cases, so did the insulating bushing on the transformer. Apparently something was wrong.

A close study of the action of the gap brought out some interesting things. It was found that the needle gap did not arc over instantly, as had been supposed but required a certain length of time. It took *five millionths of a sec.* for the gap to break down and while this may seem an infinitesimal interval, it represents the entire difference between perfect protection and non-protection.

During the five micro-seconds that was required to break down the gap, one mile of the disturbing wave had passed by and had reached the transformer where it impinged on the high inductive winding. At the transformer, the wave doubled in voltage, was reflected back and the double voltage arced over the bushing.

It is interesting in this connection, said Dr. Faccioli, to understand just why the voltage doubles when a wave is reflected in this manner. An electric current, that is, an electric charge in motion, has associated with it both electrostatic and electromagnetic energy. The electrostatic field exists whether the charge is in motion or at rest but the electromagnetic field is present only when the charge is in motion; that is, when we have a current. Now, it is a fundamental fact that the amounts of electrostatic and electromagnetic energy normally associated with an electric current are equal. The amount of electrostatic energy is equal to the amount of electromagnetic energy.

When a wave suddenly impinges upon the inductive winding of a transformer, therefore, the current as we have shown in the foregoing, instantly becomes zero. Since the current is zero, there can be no electromagnetic field associated with the charge. But what has become of the electromagnetic energy that existed just previous to the time of impingement? Certainly it could not have disappeared, for that would be contrary to the law of conservation of energy. And it has not disappeared—it has been converted into electrostatic energy. Since the amount of energy represented by the electromagnetic field was the same as that represented by the electrostatic field, it is obvious that the transformation of the former into the latter results in doubling the electrostatic field or voltage.

In this manner, during the five microseconds that elapse before the needle gap arcs over, the disturbing wave impinges on the transformer bushing, meets with open circuit conditions, the current becomes zero, the electromagnetic energy component is transformed into electrostatic energy, the voltage doubles, the wave is reflected back at double voltage and the transformer bushing breaks down.

It was apparent from the results of this study that the needle gap was not fast enough. It was also found that its slow action was due to the intense concentration of the electrostatic field between the sharp points of the needle gap. A brush discharge (Corona) gradually stretched from one needle to the other until the ionization reached a point where the gap broke down and the arc established itself.

The disadvantage of the needle gap therefore was its concentrated field. What was required was a gap with a more equally distributed field—one that would not brush over. This requirement was met in the use of the sphere gap. When the sphere gap was substituted for the needle gap, the time lag of 5 microseconds is avoided and when the disturbing wave comes along it instantly discharges to ground across the sphere gap and the lightning arrester.

Here then, Dr. Faccioli pointed out, is another case where a highly important problem was solved by the discovery that *five millionths* of a sec. were required for a spark gap to break down and arc over. It emphasizes the importance of considering the small things, the apparently negligible factors that many of us are likely to overlook.

Lightning and other locally induced high frequency disturbances at first represented a most formidable condition in the operation of transmission lines but with the successful solution of the lightning arrester problem, many of the former troubles have been eliminated.

But even with the sphere gap, it sometimes happens that the gap is set for, say, 55,000 v. and a disturbing wave of 54,000 v. comes along. This, being lower than the arcing voltage of the gap, does not discharge but continues to the transformer where it impinges on the bushing, the voltage doubles, is reflected back and then at double voltage (108,000 v.) discharges across the sphere gap. In the meantime, the insulating bushing may have arced over.

So we find that we must either make our insulating bushing strong enough to withstand double line voltage, or set the gap closer to the operating voltage. Now, it would be possible to make the insulation on our transformers strong enough so that it would need not protection, but that would be entirely too expensive. So we

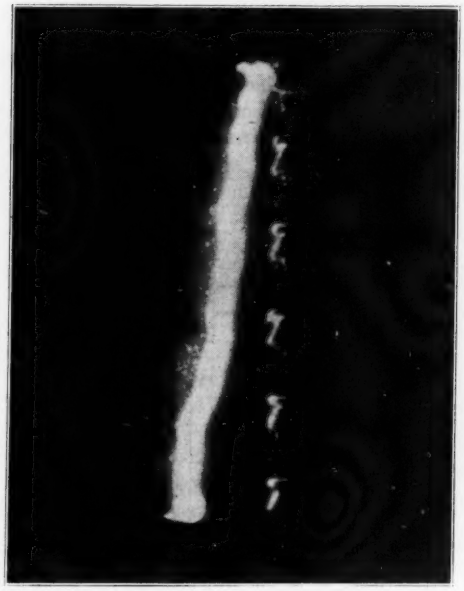


FIG. 11. FLASHOVER OF A STRING OF INSULATORS AT 1,200,000 V.

are forced to find a happy medium between the best insulating strength and the best gap setting.

The Lightning Generator

In studying the action of spark gaps and lightning arresters, it was necessary to reproduce as near as possible actual lightning conditions in the laboratory. Lightning as we have seen, is not only of extremely high voltage, but also of extremely steep wave front.

If we arrange a circuit as shown in Fig. 10A containing a spark gap G, a condenser C and inductance I, and resistance R, by means of the transformer it is possible to charge the condenser until the potential reaches a point where the spark gap breaks down. The electrostatic charge stored in the condenser then discharges across the gap through the inductance, L, and the resistance R.

It can be shown mathematically that if the resistance R is less than two times the square root of the inductance divided by the capacity the discharge will be oscillatory. Putting it in the form of an equation, if

$$R < 2\sqrt{L/C}$$

the discharge is oscillatory.

On the other hand, if R is greater than two times the square root of the inductance divided by the capacity, or if $R > 2\sqrt{L/C}$, then the discharge will be non-oscillatory.

By properly proportioning the value of the constants in this circuit then, it is possible to produce currents of extremely high wave front, and this is the principle of the so-called lightning generator which has received much publicity in the past two years.

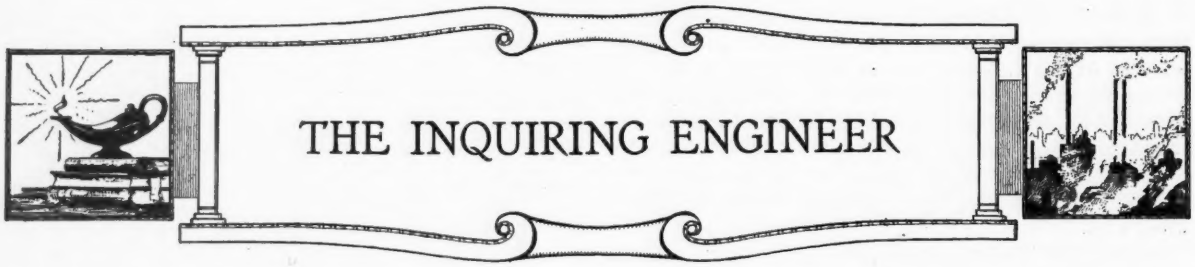
This generator shown in Fig. 6 located at the Pittsfield works of the General Electric Co. and consists of a condenser of 480 glass plates, arranged in cells or frames with 10 plates in series in each frame. These cells are readily arranged in multiple and series combinations as required. The circuit is shown in Fig. 10A. The gap G is set at some desired voltage, and the transformer voltage increased until discharge occurs. At that instant the condenser C is charged up to voltage corresponding to the gap setting. A dynamic arc forms at G and holds. This acts as a switch and the condenser discharges through the known inductance L and resistance R. The circuit that produces the impulse is shown in Fig. 10B or is in effect that shown in Fig. 10C. The condenser discharging through the known resistance and inductance causes a transient current that can be readily calculated. This current produces a transient voltage drop across R, which is the impulse voltage used in testing.

By means of this generator, said Dr. Faccioli, it has been possible to produce some interesting effects. With a seven string insulator arcing over at 450,000 v. wet and 700,000 v. dry at 60 cycles, entirely different corona effects were observed when the frequency was increased to 6,000,000. With the same string of insulators flashovers occurred when either wet or dry at the same voltage, 1,260,000. The coronas here appeared to be more intense, forming a direct luminous path between the conductor and ground without the extensive flashing close to the insulators which normally occurs at lower frequencies. The flashover of such a string of insulators at 1,200,000 v. is shown in Fig. 11.

Anchor Ice

On many occasions, covering a period of several years, engineers of various size plants have been seriously handicapped by anchor or needle ice in the intake circulating water lines. In some instances plants have operated for a long period without experiencing any difficulty, and then on a rare occasion their intake lines have been so rapidly filled with anchor ice that it was impossible to handle it by any known mechanical device.

This problem lends itself to a simple solution which is now used to reduce the anchor ice effectively to an unobjectionable quantity. The method employed is to recirculate part of the water so that the anchor ice is melted. This necessitates a connection between the outlet tunnel and intake tunnel so that a suitable portion of warm water may be recirculated. In order that proper mixing of the recirculated water and the cold intake water be effected, the recirculated water should be returned to the cold water inlet at a point some distance from the place of usage. Indications are that for proper mixing this distance should be from ten to fifteen times the average equivalent diameter of the intake necessary for maximum flow.—Powerfax.



THE INQUIRING ENGINEER

The Inquiry

One of the arguments which is advanced for private plant service in large hotels, office buildings, and certain industries, is that the demands for steam for heating and process work are such that power is produced partly as a by-product. During the summer months when the heating load drops off, or due to seasonal fluctuations in the process steam demand, the output of the private plant cannot always be maintained on an economical basis.

1. Where your organization serves such plants on an emergency or a seasonal basis, what is the general schedule of rates?

2. Do you have any large industrial plants on your lines which are interconnected with your system so that excess power is furnished to you during certain periods?

3. One of the superpower reports has suggested that large industrial plants should be interconnected with public utility systems in order to take full advantage of all possible economies. Do you believe this is feasible? If so, what do you believe to be the minimum size of industrial plant which might be so interconnected?

4. Your typical summer and winter load curves would add to the value of the discussion.

Replies

J. D. Scott, Commercial Engineer,

Portland Electric Power Co., Portland, Ore.

1. Where we serve private plants on a seasonal basis, we charge the regular schedule of rates applying to whatever class of business it falls in, but allow a waiver of the normal minimum charge for six consecutive months, which must be specified in advance by the consumer.

Where we provide emergency service for isolated plants, we also charge the regular tariff rate, but base the minimum charge per month upon 20 per cent of the cost of our investment necessary to serve that particular customer. In nearly all cases this results in a lower minimum charge than we provide for in our standard tariff rates. It is sometimes difficult to determine the cost of our investment to serve, especially where a number of customers are taken from one feeder or one bank of transformers. In most of the cases, however, this can be determined with fair accuracy by an engineering analysis and we have not experienced any difficulty in satisfying the customers on this point.

2. We have had only one large industrial isolated plant interconnected with our system, and with the single exception of an emergency which arose for a short time during the war in 1917 we have never received power from their generating plant. It is not our practice to encourage this class of business, and I doubt if in the future we will interconnect with any more such plants.

3. This is partially answered in the last question. We do not believe such interconnection feasible chiefly for the reason that the voltage regulation provided for by the average isolated plant is not comparable to that which we provide on our system and, consequently, results in fluctuations upon our lines in that vicinity at such times as we are receiving energy from their generating plant. Also, the presence of such a plant presents an additional source of accidental trouble to the system and increase the difficulties of the operation of our system because it is necessary for our operating engineer to draw up a set of rules

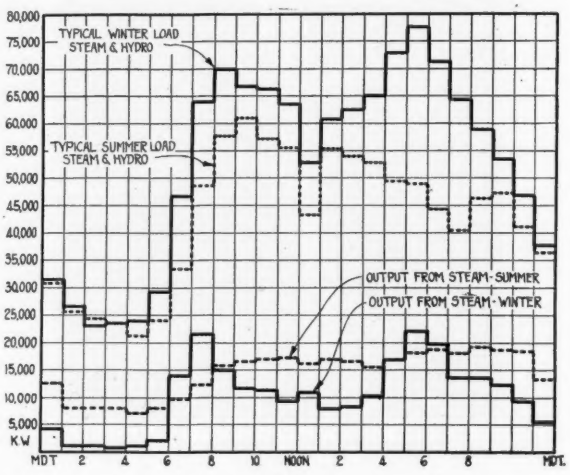


FIG. 1. TYPICAL SUMMER AND WINTER LOAD CURVES OF THE PORTLAND, ORE., ELECTRIC POWER CO.

which must be strictly adhered to by the isolated plant's engineer in cooperation with our load dispatcher.

Over a period of years the isolated plant is apt to change engineers, and such things are done frequently without notification to the company. In case of an emergency, the new engineer may not be familiar with the operating rules, and even if they are posted on the wall of his engine room he may not take the time to read them. You can readily see, therefore, that the difficulties of such operation are enhanced by this condition and are, therefore, from our standpoint to be avoided.

Our opinion as to the minimum size of isolated plant which might be so interconnected is that such a plant should have a generating capacity of not less than 1000 kw. Our reason for this is that plants less than this size are frequently not equipped with proper voltage regulating devices nor spare transformers, and in many cases there are not a sufficient number of skilled operators on the job 24 hr. a day. In isolated plants of 1000 kw. and over, these conditions are more satisfactorily dealt with.

4. See Fig. 1.

ALEX DOW, President,

Detroit Edison Co., Detroit, Mich.

The question is an old one and its answer will be local, having reference to latitude and seasons and particularly having reference to the particular requirements of each customer. Our own policy is to encourage the larger industrial plants to make their own power to such an extent as will coincide with their heating requirements, so far as these can be predetermined. With most of the industries with which we have to deal this policy works very well. In certain other industries it would be all wrong.

Answering your specific questions:

1. We have no season rates for the cases which you have in mind. There is always some suitable standard rate. For business which is essentially summer business —open air amusement parks, etc.—we file class rates, but these would not enter into the present discussion.

2. We have at the present time no connections from which we receive excess power. This condition is peculiarly due to the long time application of the business policy outlined above. In brief, there are few industrial plants in our territory—if any—which could sell any measurable amount of excess power.

3. That "superpower" suggestion is almost as old as the industry. It is in effect in a number of places and has been for years. A notable instance is the interconnection between the Lehigh Electric system and the Bethlehem Steel Co. The minimum size of industrial plant which might be a profitable connection would tend to be some function of the size of the electric power system. The operating standards of the plant and its qualification to operate in synchronism will be at least of equal importance with its kilowatt capacity.

4. Our typical summer and winter load curves are much more influenced by seasonal and other variations of industrial activities than they are by variations in the steam heating requirements of our customers.

M. E. SKINNER, Commercial Manager,

Duquesne Light Co., Pittsburgh, Pa.

1. Our regular power schedules which cover service to office buildings contain a clause waiving minimum monthly payments during those months when on account of the steam heating load the requirements of the building or industry for electric service may be furnished from exhaust steam utilized for heating.

2. At the present time we have no large industrial plants with which we are interconnected. We serve considerable power to steel mills who generate their own power but in general we are not operating in parallel with their systems but rather supplying a definite block of their load for which they either do not have adequate capacity or else it is located remotely from their generating plant.

3. At the present time we are working actively on the development of a low-pressure turbine installation governed by the requirement for exhaust steam which can be operated in parallel with our system in such a manner that coal would be burned only as made necessary by the exhaust steam requirements of the installation and that every pound of steam passing to the heating system would deliver its full share of electrical energy before being utilized for steam heating purposes. This matter is up with the manufacturers but at the present time we have no tangible results on any installations of this character.

We are also negotiating with several of the steel companies for interconnections whereby we may utilize the waste heat available over Sundays and holidays, and at the same time supply a certain amount of their load during the week. We have made no calculations on the minimum size of industrial plant which might be so interconnected, but we believe it to be of the order of 300 kw.

4. See Fig. 2.

S. D. HEED, Vice-President,

Union Gas & Electric Co., Cincinnati, Ohio.

Conditions in the territory served by our lines are not comparable to a large industrial center where there are undoubtedly industrial installations of sufficient magnitude to bring up the question of interconnection with utility systems. We have no industrial plants tied in with our system where it would be possible to draw power from the industrial plant for our system operation, nor do we have any industrial installations of sufficient size to warrant such interconnection. We believe there are few industries, hotels or office buildings where central station service cannot be used economically. The advantages gained by unlimited service available 24 hr. of the day without the necessity for overtime or extra shift operations, together with the convenience factor, the absence of noise, vibration and dirt, more than offset the arguments advanced regarding process steam requirements. Heating can usually be done with low pressure steam which, combined with central station service, will take care of the full requirements of a customer with the greatest economy and convenience.

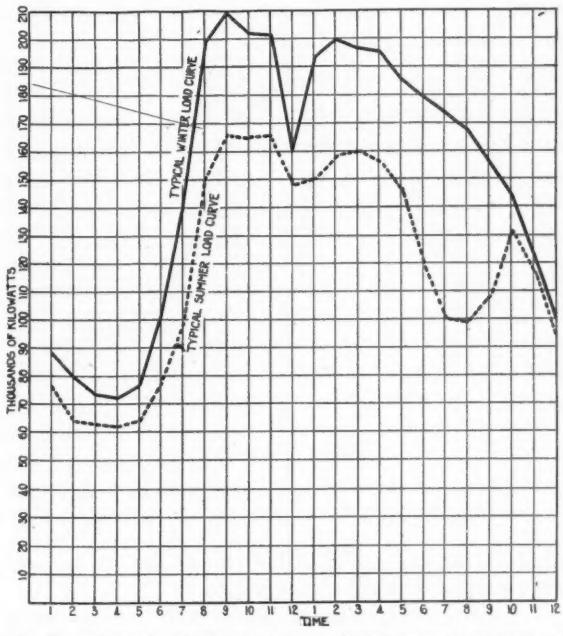


FIG. 2. TYPICAL SUMMER AND WINTER LOAD CURVES OF DUQUESNE LIGHT CO., PITTSBURGH

Usually rate schedules are on a yearly basis and emergency or seasonal loads should carry proper provisions for such service as compared with the customer who works an investment at a reasonable load factor on a yearly basis.

W. H. Hough, Assistant to President,
Cleveland Electric Illuminating Co., Cleveland, Ohio.

1. You will find enclosed copies of our Large Commercial Schedule applicable to loads of over 5 kw. demand and our Emergency Schedule. The latter has been seldom used as there have been but few cases where the emergency schedule was applicable.

Note: The Commercial Schedule referred to calls for $2.20 per kw. monthly demand charge for the first 50 kw. and $1.00 for all excess over 50 kw.; an energy charge on a monthly basis of $0.03 for first 2500 kw-hr. $0.015 for next 37,500 kw-hr., $0.010 for next 60,000 kw-hr. and $0.0085 for all excess over 100,000 kw-hr. and a 3 per cent discount for primary metering. The emergency schedule calls for a rate of $0.05 per kw-hr. for all electricity used with a minimum charge of $36 per hr. per kw. of demand. Within this minimum charge electric current may be consumed during any period of the year at the five per cent rate without additional cost.—Editor.

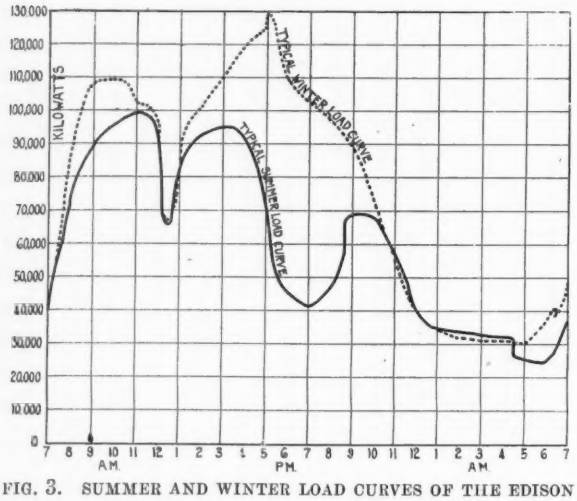


FIG. 3. SUMMER AND WINTER LOAD CURVES OF THE EDISON ELECTRIC ILLUMINATING CO. OF BOSTON

2. We do not exchange power with any industrial plants and there are none in our territory of a capacity to warrant connection to a super power system of any considerable size.

3. The minimum size of plant which should be connected to a super power system is so dependent on the size of the system, the capacity of the plant and other factors such as operating conditions that no general statement could be made on this subject.

L. R. Wallis, Superintendent, Sales Department.
Edison Electric Illuminating Co. of Boston.

1. Supplementary service rate S is used. Note: This supplementary service is available in lieu of use of the customers' other sources of power which at all times are kept in readiness for use upon reasonable notice, the service being supplied solely at the convenience of the company as supplementary or secondary supply, and the customer providing at his own expense such time switches, circuit breakers or other apparatus as in the judgment of the company are necessary to protect it against the use of the service other than at times convenient for the company. The low tension alternating current rate is based on $0.095 per kw-hr. for first 500 kw-hr.; $0.03 for next 4500 kw-hr.; $0.011 plus coal for the excess. Where high tension service is supplied, the $0.011 rate is in effect for the next 95,000 kw-hr. above 4500 and $0.008 per kw-hr. plus coal charge for the next 900,000 kw-hr. For additional consumption, the rate is reduced to $0.0075 plus coal charge for such portion of the excess as is taken during hours specified by the company. The added cost of coal above $3.75 per long ton is pro-rated according to the kilowatt-hours manufactured and sold at the company's generating stations with adjustments to cover distribution losses. The minimum charge for supplementary service is $120 per year.—Editor.

2. No.

3. Several large industrial power plants are operated in parallel with our system. This has been done either to derive a portion of their power from steam, otherwise required for heating, or to depreciate existing plant investment by the purchase of that portion of their power under an off-peak rate, operating their plant during the few hours of the public utility's peak load.

Water powers are also operated in parallel with our system when water is available. In every case, however, the capacity of the private power is only a portion of the total power requirement during working hours. After working hours the actual value of this power to the public utility, its uncertainty, and the price that could be offered for it, would generally not warrant its development.

If an industrial plant of any size has a reliable water power, we believe it should be developed, if it is available at times of the plant's maximum demand.

The advisability of interconnection of the industrial plant with the public utility is not dependent on the size so much as it is on the cost of this connection and the benefit derived in each case.

4. See Fig. 3.

Impurities that Spoil Batteries

AN INVESTIGATION is now in progress at the Bureau of Standards for the purpose of ascertaining the harmful effect of impurities in the electrolyte of automobile and other storage batteries. Results up to the present time have shown that some impurities are harmful to both plates of the battery, some to only one, while still others have no apparent effect.

The investigation has now been in progress for more than a year, the plates being immersed in electrolytes to which known amounts of impurities have been added Provision is made for measuring easily their change in weight, and the electrolytes are kept at constant temperature by means of an oil bath.

The object of the investigation is to obtain information necessary to the successful operation of storage batteries, and to serve as a guide in the preparation of specifications for sulphuric acid for the electrolyte.

A paper is now in course of preparation embodying the results. Data obtained to the present time indicate that among the impurities which affect both positive and negative plates are iron, manganese, chlorine, and the bichromates. Bismuth, starch, and sugar affect the positive plate but not the negative; while platinum, tin, copper, antimony, silver, nitrogen, and tungsten affect only the negative plate. Among the many substances which appear to produce no harmful effect are mercury, alum, titanium, calcium, zinc, cadmium, sodium sulphate, and tannic acid.

Centrifugal Fans and Their Characteristics

PART II. A STUDY OF THE CHARACTERISTICS OF FANS AND THEIR ADAPTABILITY FOR VARIOUS SERVICES. BY R. T. LIVINGSTON*

WITH THE MORE general appreciation of the use and application of centrifugal fans, there has appeared upon the market a wide variety of types of fans, and the engineer confronted with the task of selecting the best fan for a particular purpose must be reasonably familiar with the characteristics of various types.

In the majority of cases these various forms of construction are not just due to the manufacturers' or designers' whims but rather changes in form to meet higher pressures, greater volumes or higher speeds. Each one of these types has a different characteristic which fits the fan for some particular service requirement and it is the object of this article to point out the peculiarities of characteristics which are found with each type of construction.

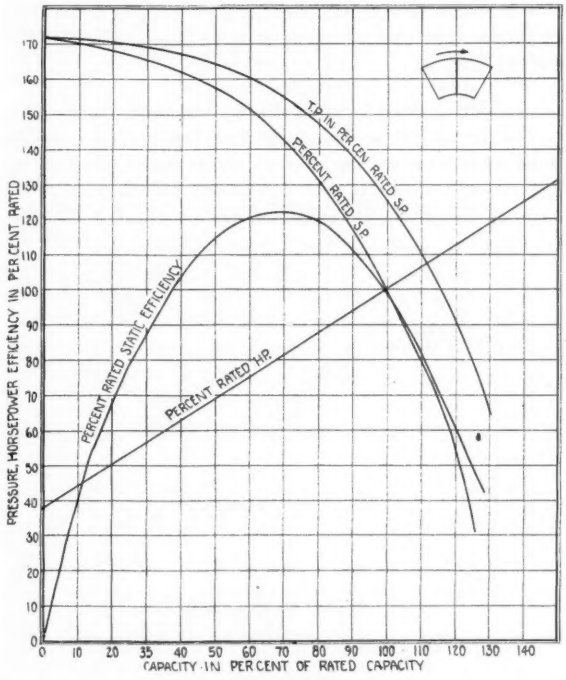

PRESSURE, HORSEPOWER EFFICIENCY IN PER CENT RATED
CAPACITY IN PER CENT OF RATED CAPACITY
T.P. IN PER CENT RATED S.P.
PERCENT RATED S.P.
PERCENT RATED STATIC EFFICIENCY
PERCENT RATED H.P.

FIG. 1. TYPICAL CHARACTERISTIC CURVE FOR STEEL PLATE FAN

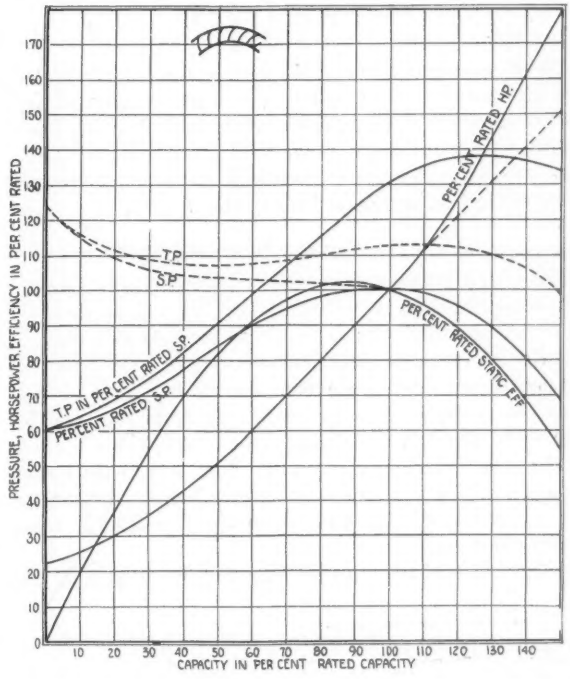

PRESSURE, HORSEPOWER EFFICIENCY IN PER CENT RATED
CAPACITY IN PER CENT RATED CAPACITY
PER CENT RATED H.P.
T.P.
S.P.
PER CENT RATED STATIC EFF.
T.P. IN PER CENT RATED S.P.
PERCENT RATED S.P.

FIG. 2. TYPICAL CHARACTERISTICS OF MULTI-VANE TYPE OF FAN

Figure 1 illustrates the curve for one form of the "steel plate fan." The straight line horsepower curve and rapidly drooping static pressure curve are typical for this type of fan. The latter is exceedingly useful for determining operation in parallel. When two fans of this type are operated together at the proper place on their characteristic curve, it is practically impossible for them to divide the load other than as designed and even if the static pressure against which one operates changes it is not necessary for the fan to shift its point of operation much. This static pressure curve gives a rise of pressure with a decrease of quantity, which may be a useful point especially when there is a momentary increased resistance which must be overcome, such as is often the case in forced draft work. The principal objection to this type of fan is the fact that the horsepower curve rises steadily and has no peak, hence there is a tendency for the fan-motor to become overloaded if the static pressure is removed, also the curve droops so rapidly that the capacity of the fan is small for its size. The speed of this fan is in general comparatively slow which unfits it for direct connection to an electric motor or steam turbine. Another point of interest is the large area of the fan passages which makes it possible to use this fan when there is to be large quantity of material in suspension in the air or gas handled.

THE MULTI-BLADE FAN

The next fan illustrated and probably also in point of date of development is the forward curved blade "multi-blade" fan, see Fig. 2. This fan may have almost any shaped curve between the limits shown, depending upon the manufacturer. Probably the oldest is the one shown in full lines. The concave upward or nearly straight horsepower curve and the relatively constant static pressure curve, S. P. characteristic of this type of fan. This static pressure curve is secured due to the fact that the air on leaving the blade has a rotational component greater than the tip speed of the fan. For certain services where a constant static pressure with a varying capacity is desired, this fan may be very desirable. The horsepower curve, however, presents a constant danger and if there is the slightest possibility that the resistance against which the fan operates may decrease, it is necessary to have a fan motor considerably larger than is needed at the correct

*Mechanical Engineer in Charge of Hydraulic Machinery Courses, Columbia University, New York, N. Y.

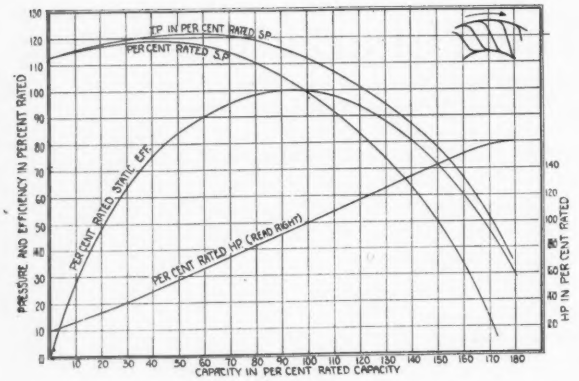

TP IN PER CENT RATED SP
PER CENT RATED S.P.
PER CENT RATED STATIC EFF.
PER CENT RATED HP (READ RIGHT)
PRESSURE AND EFFICIENCY IN PERCENT RATED
HP IN PER CENT RATED
CAPACITY IN PER CENT RATED CAPACITY

FIG. 3. CHARACTERISTICS OF FAN WITH DOUBLE CURVED BLADES

point of operation. Then, too, if it is desired to operate two of these fans in parallel they must be operated far beyond the point of best efficiency, which is obviously inefficient. From the shape of the total pressure curve, T. P. it may be seen that this is essentially a volume or velocity fan and for that service will do excellent work.

Fans With Double Curved Blades

In Fig. 3 is shown the characteristic of a multi-bladed fan having double-curved blades or "partial backward." The idea of this design is to secure the desirable characteristics of the steel-plate fan and at the same time the volume of the multi-blade fan. In the best fans of this type the horsepower curve bends over from the straight line. The droop in the static pressure curve exists but not to the same extent as in the steel plate, due to the larger capacity of this fan. This fan is a higher speed fan than the modern steel plate fan whose characteristic is practically the same.

The full backward curved vane fan, see Fig. 4, is the

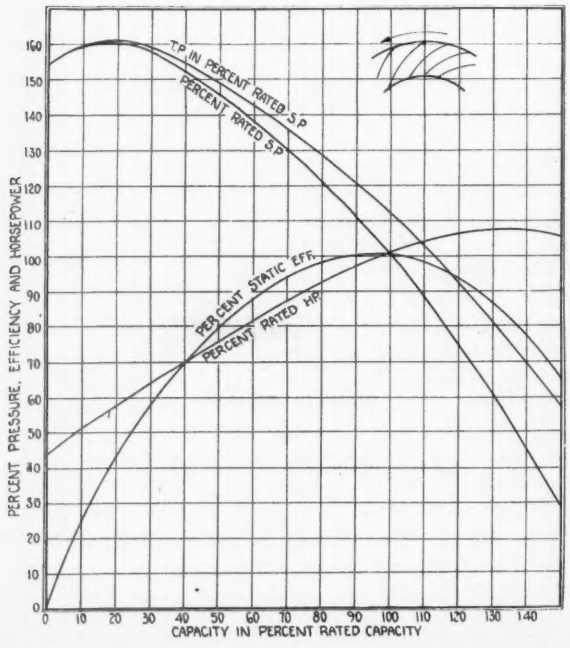

TP IN PERCENT RATED S.P
PERCENT RATED S.P
PER CENT STATIC EFF.
PERCENT RATED HP
PERCENT PRESSURE, EFFICIENCY AND HORSEPOWER
CAPACITY IN PERCENT RATED CAPACITY

FIG. 4. TYPICAL CURVES OF FAN WITH FULL BACKWARD CURVED VANES

furthest development of the idea of high-speed drive. Here, due to the backward curve, the static pressure is relatively low though on account of the high speed almost any pressure desired can be obtained. The pressure curves are similar to those of the steel plate fan but the capacity is much greater, hence the curves are not as steep. The important feature is the shape of the horsepower curve which reaches a maximum and then bends over, giving an automatic self-limiting device so that it is impossible to overload the motor of a properly designed unit.

There is one other multi-blade fan which is an intermediate development between the forward and the backward curved vanes and that is one whose vanes are forward curved at inlet and radial at outlet. As might be expected, the characteristic curve is also intermediate, the total pressure being constant as long as the air follows the blades and the horsepower curve being practically a straight line.

Propeller or Axial Flow Type of Fans

The propeller type or axial flow fan gives a peculiar characteristic curve, see Fig. 5. The design of the fan

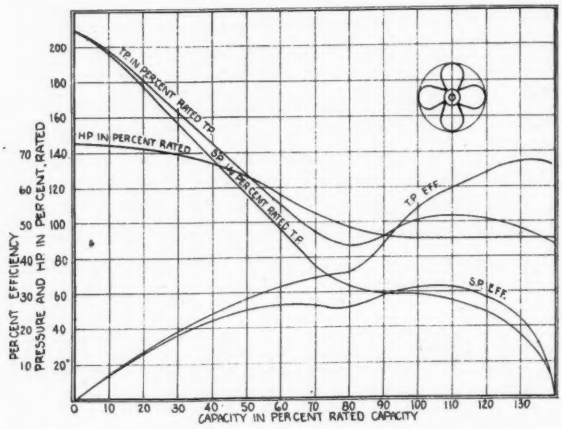

TP IN PERCENT RATED TP
HP IN PERCENT RATED
SP IN PERCENT RATED TP
T.P. EFF.
S.P. EFF.
PER CENT EFFICIENCY
PRESSURE AND HP IN PER CENT. RATED
CAPACITY IN PER CENT RATED CAPACITY

FIG. 5. CHARACTERISTICS OF AXIAL FLOW OR PROPELLER TYPE FANS

modifies the shape of these curves to a great degree and any curve may differ widely from the ones shown here; however, there are certain general features which cannot be eliminated and which are inherent to this type of fan. The hump which is found in all the curves can never be entirely removed and is due to the fact that as the static pressure against which it is operating increases the fan changes from operating as a true axial flow fan and tries to operate as a true centrifugal fan. That is to say a particle of air cannot be discharged against a higher pressure than it possesses itself at that instant and in consequence it climbs the blade until it reaches a point where the tip-speed of the blade is sufficient to give it enough pressure to be discharged. It is on account of this fact that in poorly designed fans or fans which are operating against static pressures for which they were not designed, there may be a flow from the discharge to the suction side at the "eye" of the fan. This is overcome in many fans by making the hub of the fan of large size. The falling horsepower curve is found only in this type of fan and is exceedingly useful, as it removes all danger of overloading the fan when static pressure is removed. While the pressure characteristic is not the best possible, it still is pos-

sible to operate these fans in parallel at any part of their curve except at the flat portion.

These six types of fans are the most common which will be met in practice and though the characteristics may be modified by the use of evase nozzles and special forms of casings, yet in general they will conform to the illustrations given herein.

Mr. Hagen of the Sturtevant Co., when speaking before the Stokers Mfg. Assn., gave the requirements of a fan for forced draft service as follows:

1. Reliability.
2. Successful parallel operation.
3. A reserve of pressure.
4. High static efficiency.
5. A high speed.

The first point is assured by the purchase of the fan from any reputable manufacturer in whose interest, as well as the purchasers, it is to have reliability and who will make good on any defect. On the second and third points we must dismiss the forward curved and the radial tip, multi-blade fan, leaving us the steel plate, the double curved, the full-backward and the axial flow fan. A high static efficiency is not usually found in an axial flow type and the steel plate fan is not well adapted for high-speed drive. Therefore we may say that the fans assume the following order of merit: Full backward, double curved, axial flow, steel plate, radial tip and last the forward curved. This order must not be taken as definitely settling where each fan belongs for we must keep in mind that after all the yearly cost basis is the one to judge on and it may be that the lower cost of the propeller type and the steel plate will overcome their other disadvantages and change their position.

Fans for Induced Draft Service

The requirements for induced draft are entirely different from those for forced draft. Here we have a high temperature and one that may fluctuate widely, large quantities of soot, and cinders which are deposited upon the fan blades and large quantities of excess air which may leak through the boiler setting especially as they dry and the flues alternately expand and contract with the variation of temperature. Best practice calls demands that induced draft be only used alone when the loss through the stoker is small such as in chain grate stokers and in other cases that the induced draft fan be called upon only to overcome a little more than the resistance of the boiler proper, flues, economizer, etc. As this resistance varies but slightly the choice of fan will usually be dictated by other conditions than characteristic. Where high-speed drive is not required, the steel plate fan is ideal as the deposits of soot, etc. are small in proportion to the air areas and there is little chance of the fan getting out of balance. From the quantity of air to be handled is to be considered the forward curved multi-blade fan becomes the choice and its adaptability to high-speed drive is another factor in its favor. Other types of fans may be used if circumstances warrant but as a general rule, it will be found that one of the above-mentioned is the choice of the fan manufacturer.

In the next article of this series the method of selecting a fan for a given service will be explained and the effect of changes of temperature and density, indicated.

Waterproof Basements for Power Plants

Water Seepage into Power Plant Basements Can Be Avoided Provided That the Walls and Floors Are Properly Constructed

POWER PLANT construction is often concerned with the proposition of building the basement walls so they will be water tight. This is of course of greater importance where switch gear and electrical appliances are located in the basement than it is under the boiler room. Making walls water tight is largely a matter of carefulness and good workmanship so that all power plant basement walls, regardless of location, should be water tight.

Masonry walls are difficult to make water tight, particularly in locations where the soil is heavy and drainage is poor or ground water level rises above the basement floor level during protracted wet weather. The chief reason for this is the numerous mortar joints. Monolithic concrete being of one mass is therefore particularly adapted to basement construction under such conditions.

In the construction of a basement the walls must have sufficient strength to support the load placed upon them and to resist the pressure of the earth outside. The base or footing should be of such width that the load is evenly distributed without exceeding the safe bearing power of the soil at any point, thus preventing unequal settlement.

In mixing concrete for the walls, only sufficient water should be used to produce a plastic or quaky mixture; a drier concrete is likely to be porous in spots and a sloppy mixture is certain to produce a weaker wall. The concrete should be placed in the forms in as continuous an operation as possible, to reduce construction joints and seams to a minimum and it should be well spaded. Concrete should be placed in layers not deeper than 12 in., taking care to avoid vertical joints or inclined planes. When it is necessary to stop work while placing concrete for a well, the concrete should be left level in forms and roughened on top. On resuming work, clean the surface of all foreign material, drench it with water and immediately cover with a 1-in. layer of 1:2 cement-sand mortar following this at once with the next layer of concrete. If desired a bevelled, 2 by 4 timber, narrow side down, pressed into the fresh concrete above the center line of the wall, will form a groove which, when filled with the new concrete, adds much to the watertightness of the joint. The selection of aggregates, proportioning, mixing and placing of the concrete should follow recognized good practice.

All down-spouts from roof gutters should be connected to underground drains or else arranged so as to discharge water away from the basement wall. If down-spouts are not used, a concrete gutter should be built against the basement wall at ground level and sloped to a drain leading to a dry well or connecting with the sewer outlet some distance from the house.

In regions of considerable rainfall or where the soil is heavy and natural drainage is poor, a richer mixture of concrete (1:2½:4) should be used for the walls and the

base of the floor, in order to provide a denser concrete and thus better resist seepage. As an added precaution, the outside surface of the wall may be plastered with a ⅜-in. coat of 1:1½ cement-sand mortar applied as soon as possible after the forms are removed. In some sections it is common practice to mop the surface of the wall with a coat of hot tar, pitch or asphaltum but the main reliance should be placed upon the uniform density of the concrete wall, secured through careful construction.

Joints between walls and floors should be constructed with a wedge-shaped groove with bottom wider than the top and filled with tar or pitch. Strips of wood, inserted when the floor is laid and removed after the concrete has hardened can be used to form the groove. If concrete walls and floor are carefully built, there is little danger of water seeping through them.

Where drainage of surface water run-off from the roof to a suitable outlet is possible, it is desirable to place a line of drain tile around the outside of the basement level with the footing. Down-spouts from the roof can be connected with this line. The trench excavated for laying the tile should be backfilled with cinders, or coarse gravel to within a foot or so of the surface, finished with material taken from the trench and sodded over. Joints between tile should be wrapped with pieces of burlap or sacking to prevent any dirt or sediment filling the line and it would be best to cover the line with a layer of larger stones to a depth of about one foot before filling the trench with cinders or gravel.

Where the location of the basement is such that the ground water is close to the floor level and during rainy seasons is likely to rise above it, further precautions should be taken to prevent leakage since the construction becomes similar to the building of a tank, excepting that external and not internal pressure must be provided against. Floor drains in the cellar should have backwater or seal traps to prevent flooding the basement. In general the thickness of wall ordinarily used will be found sufficient for the water pressure likely to be encountered but when there is a head of water of 4 ft. or more above floor level, thicker walls or reinforcement may be necessary.

Water Pressure Which Will Exist

For every foot that ground water rises above floor level, a water pressure of 62½ lb. per sq. ft. is developed against the outside of the walls and a similar upward pressure against the under side of the floor. While the conditions of the ground may be such that the actual pressure upon the walls is less than this amount, it is customary as a factor of safety to assume that the full head of water may be exerted and to design accordingly.

If an unreinforced floor is used it must resist by its own weight the water pressure from below. Considering that concrete 12 in. thick weighs approximately 144 lb. for each square foot of surface area, the unit weight of floor becomes 12 lb. per sq. ft. for each inch of thickness. A 5-in. slab is, therefore, needed to resist the upward pressure of a 1-ft. head of water. In cases where plain slabs would be excessively thick, a reinforced slab would undoubtedly be more economical. Such a slab would be anchored to the walls and to intermediate partitions for columns, if present, to obtain the necessary support.

Mixtures Commonly Used

In the construction of basement walls to resist water pressure a 1:2½:4 concrete can be used, excepting under extreme conditions of outside water pressure when a 1:2:3 mixture, commonly specified for water tank construction, should be used. The same is true for the basement floors.

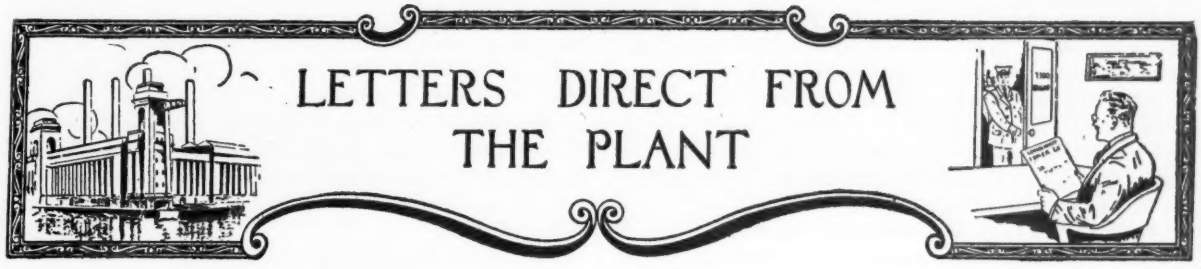
In order to provide a further seal against entrance of ground water a membrane composed of several layers of tarred felt or burlap mopped with hot tar, pitch or asphaltum should be placed on the floor, across the footing and continued up the outside of the wall. Under such conditions the wall footing is constructed first and then either a line of brick embedded along the center line of the wall so as to form a ridge or break or a chamfered groove formed in the footing as a key. When the concrete has hardened a layer of burlap or prepared waterproofing felt is placed over the footing, the surface of the concrete having been mopped with hot tar or asphaltum and if the groove is used the key should be completed by pressing down the fabric into the groove with brick well bedded in cement mortar. This strip of material should extend about 3 ft. beyond the face of the wall on each side and should be turned up on the outside and lightly fastened to the inner face of the outside wall form. Two inches of 1:2½:4 concrete should be laid over the entire floor area. When this is hardened sufficiently it should be mopped with tar, the inner sheet of burlap turned down on the floor and then covered temporarily in such manner that it will not be injured during the construction of the wall. The inner wall form may then be set up and the wall built to full height.

After the forms are removed, clean the surface of the concrete floor, mop it well with tar or pitch and cover it with several layers of burlap or tarred felt which will overlap the sheet extending out from the wall. The successive layers of burlap or felt should be placed so as to lap joints with the preceding layer. The balance of the floor should then be laid in alternate slabs, coating the joints with tar as previously mentioned.

Burlap on the outside of the wall should be mopped thoroughly with tar and the whole wall surface below ground line covered with a membrane similar to that used for the floor. In order to protect this membrane from damage the wall should then be covered with 1 in. of 1:2 cement mortar applied in several coats. If preferred, however, a wall of concrete 3 or 4 in. thick may be constructed on the outer edge of the footing first, the waterproofing membrane laid over the footing and extended up this wall and the main concrete wall then constructed, using this thinner wall as the outside form.

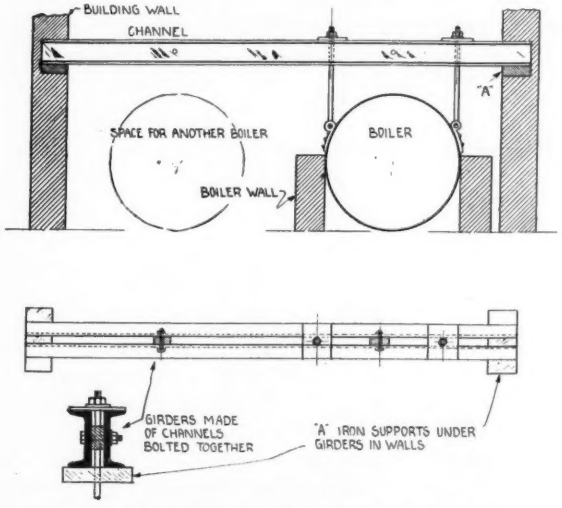
In all of this work it is understood that construction should be carried out when the excavation is dry. Otherwise a sump must be dug near the outside of the building from which ground water can be pumped so as to keep it away from the building. If the concrete is deposited in water or there is seepage of water through the concrete at the time of construction, the work will not be satisfactory.

Air compressor inlet and discharge valves should be removed occasionally and cleaned and by observing them it can be determined whether the cylinder is receiving the proper amount of oil. The surfaces should show a greasy appearance, and not be dry.



Two Boilers Suspended Without Columns

IN A CERTAIN power plant an additional return tubular boiler was installed in a brick building which formerly had been used for another purpose. The boiler was to be suspended entirely independent of the walls.



DETAILS OF GIRDER SUPPORT FOR TWO BOILERS

At first it was intended to make the suspension for one boiler only, but after giving the matter a little more thought it was decided to arrange the suspension for two boilers, as the building was large enough to house two boilers of the size being installed and it was thought that in the near future it might be necessary to install another boiler.

In the suspension of the boilers, no columns were used. Heavy channels were used to make the girders and in place of using columns to support them, holes were cut in the side walls of the building as shown in the illustration, Fig. 1. The girders were long enough to reach across the entire building and into the building walls. To give the girders an even support in the walls, iron supports were placed under each end of the girders in the holes of the building wall as shown at A in the sketch. Then the girder ends were masoned solidly into the walls.

After the new boiler was in service no vibration was noticed in it.

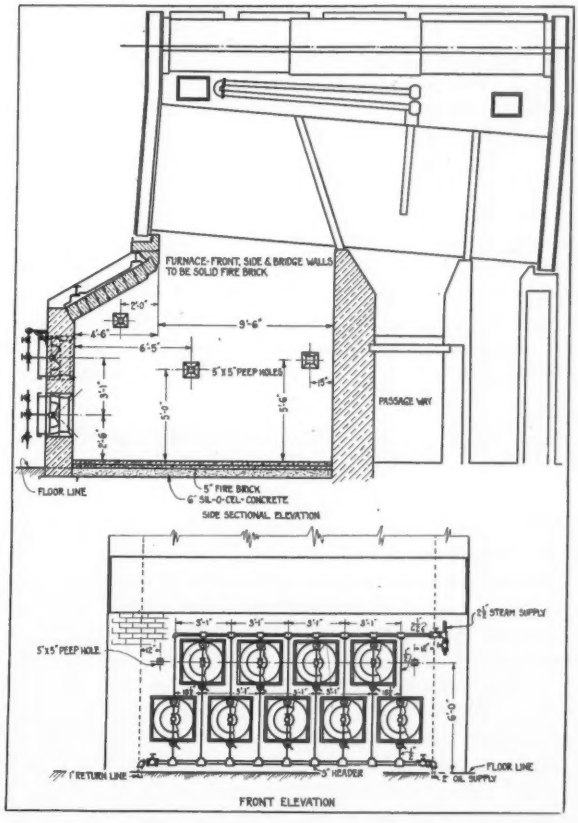
I believe that the arrangement for suspending the two boilers in this way was much cheaper than other methods, taking into consideration that the price of 4 or 8 columns is eliminated.

This arrangement for suspending two boilers without columns may be of interest to some other reader who might desire to build such a boiler room. The girders could be placed in the building walls while they are being erected.

Milwaukee, Wis. H. A. JAHNKE.

Novel Boiler Setting for Oil Burners

IN THE May 15th issue of Power Plant Engineering, page 527, is shown a boiler setting under which these words appear: "Maximum possible furnace volume is obtained with rear shot burners."



INCLINED ARCH AIDS COMBUSTION IN OIL-BURNING FURNACE

It may be true that maximum furnace volume is obtainable by means of rear shot burners but the view in the above-mentioned article does not show the possibility of increasing furnace volume still more by the use of an inclined arch as shown in the accompanying illustration.

This installation was made for a large sugar concern in Cuba by the Engineer Co., of New York City, and I believe the design will be of interest to the readers of Power Plant Engineering.

One of the disadvantages of the use of the horizontal arch in an installation of this kind is that it reflects the heat downward onto the floor and side walls and these in turn reflect the heat back and the combination of radiant heat, reflected heat, and the flow of hot gases along the arch inevitably results in the spawling of the refractories and ultimately in the failure of the arch. This action is known as multiple reflection.

With the inclined arch as shown, the radiant heat is reflected into the furnace and especially that part of the furnace where the oil is being burned, which tends to raise the flame temperature and facilitate combustion.

In addition, the inclined arch permits a greater area of white flame to be "visible" to the tubes which is always advantageous. The heat is not first reflected to the floor in such a way that it will be reflected back to the arch, and there is a quick flow of gas and air along the inclined surface of the arch which tends to keep it cool and prevents its failure.

There is another point which is that the oil flame should normally enter into an expanded volume of furnace because of the fact that the air and gases of combustion expand more rapidly with the increased temperature. This they are not permitted to do when burned under a flat arch but they are permitted to do so when they are burned under the inclined arch.

Mechanical burners were installed in this plant in two tiers as indicated—one row over the other. An arrangement of this kind is impossible with steam jet burners.

This is a 1000-hp. boiler which was originally run on bagasse but the owners desired to concentrate all of their oil burning to one boiler, consequently this boiler was converted over for that purpose. To increase the furnace volume they introduced the inclined arch. Nine oil burning conical flame steam atomizers within registers are used and they develop a total of about 2700 hp.

Newark, N. J. W. F. SCHAPHORST.

Hints on Ammonia Compressor Operation

REFERRING to the article on page 1069 by G. U. Swann, I wish to state what we are doing in the hotel where I am employed.

They have had several bad blow-outs of ammonia lines and heads, caused by careless engineers starting with the discharge valves closed. So now the orders are to leave the suction and discharge valves both open when stopped.

I have had several years of refrigerating work and this is a new one on me. After the compressor is shut down, the engine room is a fine place to be in—I don't think! The outfit is used for ice making and brine circulation for the various coolers about the hotel and, as this is a large place, there are several of these coolers.

After the machine is shut down for a short time, the back pressure goes up to about 35 lb. gage as we only pump down to about 5 lb. gage so as not to get any air in the system. Now the packing on this rod never gives any trouble when running, as we carry only 10 to 15 lb. gage and about 125 on the high side. This is a steam driven horizontal rig with a Corliss engine for power.

Lately we had some trouble with the brine coils warming up and on investigation found them full of air and this hampered circulation. After purging them of air they went to work as well as ever. This air was let in by having the brine pump open for repairs, as the valve seats, which were of brass, had worked loose and the pump did not handle the work. We now have iron seats and there is no further trouble.

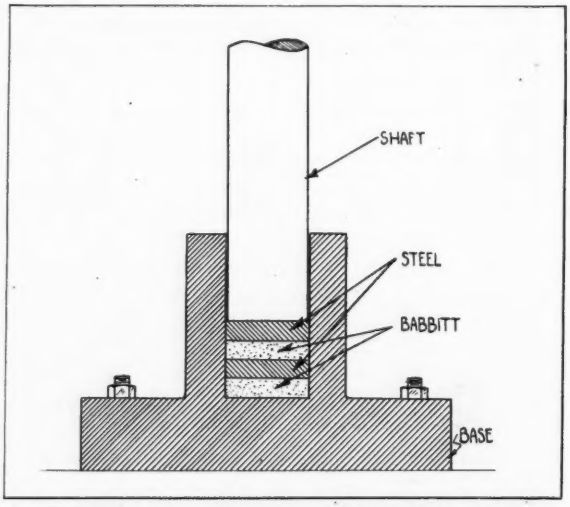
We run the compressor until the brine gets down to 12 deg. and then stop and let the brine get up to about 20 deg. So we carry a low side pressure of anywhere from 5 to 15 lb. If we get it any higher the frost comes back to the machine.

Mr. Swann is right about high suction pressures. I have used a system of charging similar to the one he shows and find it to be handy. As long as it does the trick, why worry?

Rochester, N. Y. R. G. SUMMERS.

End Bearing Improvement

IN A laundry, each large centrifugal drier had an end bearing on the shaft as shown in the accompanying sketch.



ALTERNATE BABBIT AND STEEL DISKS PREVENT HEATING

At the bottom of the cast-iron shaft chamber there were four hard steel-polished disks. The oil cups and feed pipes, used to carry oil to the bottom of the chamber, were kept clean and plenty oil was supplied, nevertheless the shafts would persist in heating and work would have to be stopped to cool them.

As an experiment, I removed two of the steel disks and replaced them with babbit disks, as shown in the sketch.

The idea worked admirably, the bearings continuing to run cool under severe service. After several years in use, I examined some of these bearings and was surprised to find the babbit disks worn thin but still on the job. The man in charge told me he had cleaned the shaft chamber out only a few times when they showed signs of heating.

Toronto, Ont. JAMES E. NOBLE.

Feeding the Boiler

INTERMITTENT BOILER feeding is undesirable. This is so because, in the first place, the periods of such feed are never, except by accident, in synchronism with or in proportion to the relation between furnace heat and boiler load. Turning on the feed water supply always entails a sharp increase in demand for heat from the furnace to heat up this water to the boiling point, while turning it off sharply

reduces this demand. Where this turning on and off is done arbitrarily, it is likely to result in wide fluctuations in the steam output of a boiler directly the reverse of what the load calls for. Second, on account of the use of economizers, feed water heaters, water softeners and modern metering instruments, a continuous rate of feed is necessary that these apparatuses may operate to the best advantage.

Best authorities now recognize that when the load suddenly increases on a boiler, it is desirable temporarily to decrease the rate of feed water supply and, on the other hand, to increase it quickly when the load on the boiler suddenly falls off. This is because changes in the rate of heat generation in the furnace always lag behind the changes in the rate of boiler demand and by varying the rate of feed water supply inversely to the boiler demand for brief periods after sudden load changes shortcomings on the part of the furnace in keeping up with rapid fluctuations are compensated for. Where steady loads or slowly changing loads are in question, the rate of feed should always be in proportion to the load.

Newark, N. J. W. F. SCHAPHORST.

Why We Decided Against Purchased Power

SOME TIME AGO I was confronted with the problem of telling the management what I thought of the advisability of purchasing central station power in place of continuing the operation of our isolated plant.

Upon investigation I found that there were several places in our city, which were getting outside power and it was costing them more for heat than it should for heat and power combined. The big reason for this is that in a simple heating plant, neither water nor steam meters are commonly used so nobody knows how much water they are evaporating with a pound of coal and so it goes from bad to worse.

In 1920, an official of a central station operating company said, under oath, it was costing them $0.0187 to produce a kilowatt-hour. The total cost was likely less than $0.0187. You see it was costing them almost 2 cents per kilowatt to make and deliver power. If the coal cost for central stations is only 20 per cent of the operation cost it would not be possible to sell power at a low figure.

In our case, whether we make power or not, the difference in labor cost will be about nil. Even in the summer time about all the difference would be the interest and depreciation on the cost of the generating unit plus coal and a little oil and water. In winter the manufacture of power costs but little.

The price the central station would offer to us would be something like this; 10,000 kw. and under $0.02 plus a service charge; over 10,000 kw. $0.018 plus a service charge. On the $0.02 rate the service charge would be $60 and on the $0.018 rate the service charge would be $90, so in either case they would receive 2½ cents per kw. Their bills would run from 9500 to 10,500 kw. Our rate would perhaps not be more than the $0.018, or even $.017 but our service charge would be higher and in the end we would be paying from 2.4 to 2.6 cents per kw-hr.

If we bought power in the summer time we would have to run a high pressure boiler and heat it up every day. I would estimate 1500 lb. of coal to keep the boiler hot and make the necessary steam. That would be from about the first of June until about the 15th of September. We have had heat on after the 10th of June a few times. Our records show that by subtracting the amount of coal necessary to keep the boiler hot, it would be easy to evaporate 8 lb. of water per lb. of coal. With a modern engine and generator it is claimed we could get a kilowatt for about 31 or 32 lb. of water; if that is so, then the coal cost would be about 1 cent per kilowatt.

Of course our old rig, even though it were put in good shape, would take quite a bit more than that, still I cannot see how the central station can compete with the isolated plant even during the 3½ mo. in summer time. In the winter time with the central stations dumping at least 60 per cent of the heat into the river and isolated plants running it into the heating systems, it is plain that the overall efficiency of the isolated plant is far ahead.

There is another feature worth thinking about. With our own plant we have been able in the past to have power when we wanted it. The central station power is off quite a good deal. The head of the mechanical department of a local mill tells me that the power has been off about 25 times a year since that mill started. He says that it is rather annoying.

It is true that the coal per kilowatt is much less in the central station than it is in our plant and it is true also that in the super power plants they are talking about, it will be still less. It is also true that by cutting down the 20 per cent expense item for coal, the larger the plant the greater will be the other 80 per cent item of operating expense. If the cost of coal were 80 per cent of the central station expense, we could not compete with them at any time that we could not use the exhaust steam.

It takes only 4 per cent more coal to make a pound of steam at 150 lb. than at 1 lb., so I conclude that it will be a waste of money to purchase central station power.

LEN SEDARG.

Pipe Lines Should Be Direct and of Ample Size

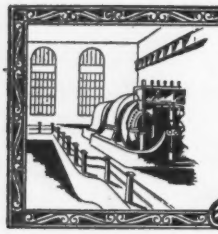
I RECENTLY had the pleasure of straightening out one of the worst refrigerating plant layouts I ever saw. An analysis of this job may be of value in pointing out how an installation should not be made.

This is a compression plant. The liquid line from the double-pipe condenser takes a vertical drop to the floor, along the floor and then up to the top of a vertical receiver. This construction forms a most excellent pocket for the accumulation of impurities. They eventually plugged up the line completely. I raised the condenser and made as straight a connection as possible to the receiver; that cured the trouble there.

My attention was next directed to the suction line. It was supposed to have been a ¾-in. pipe all the way from the expansion coils to the compressor but I found a variety of sizes there. From the ¾-in. suction header the size was reduced to ⅜ in., then raised to ½ in., through a ½-in. valve, then again increased to ¾ in. to the compressor. I took out all of this and replaced it with a ¾-in. line.

With these changes the friction load was so reduced that the plant is now easily able to operate at its rated capacity.

S. G. ROGERS.



QUESTIONS AND ANSWERS

Principles of Shaft Governors

WHAT IS a shaft governor? A. T.

A. There are two types of shaft governors, the centrifugal and the inertia. In the construction of the centrifugal governor (Fig. 1) weights are hung on the flywheel so that, under the action of the centrifugal force corresponding to a desired speed of the engine, they will assume a definite position determined by the amount of centrifugal force opposing the pull of the springs. Any variation of the weights from this position produces a change in the position of the eccentric controlling the valve. It is necessary, therefore, that the weights be suspended so that they are free to move radially. If by reason of a dropping-off in the load the engine tends to increase its speed, the weights will tend to move farther out from their original position; this tendency is, of course, opposed by the tension of the springs, but if there is an appreciable increase in engine speed there will be an appreciable movement of the weights, which will advance the position of the eccentric by means of suitable linkage. This advance results in an earlier cutoff, which means that less steam is supplied to the cylinder. The M. E. P. of the engine is therefore, reduced, and the machine resumes its normal speed.

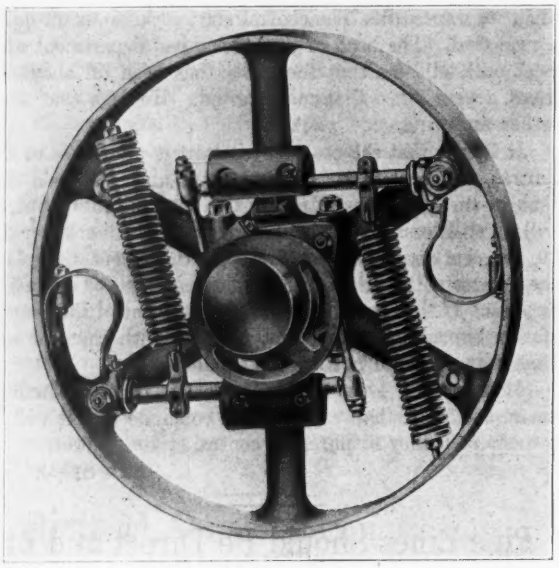


FIG. 1. MODERN CENTRIFUGAL GOVERNOR, SHOWING WEIGHTS, TENSION SPRINGS AND ECCENTRIC LINKAGE

In the inertia governor, a typical specimen of which is shown in Fig. 2, the weights are hung so that they rotate about the shaft as a center. At the same time they are free to rotate about the pin on which the weight arm is pivoted. Under the action of centrifugal force working against the spring, the weights will assume a definite position at normal speed. Now if the engine speeds up, the weights will tend for an instant to continue at the same rate of speed at which they were traveling; that is, they obey the principle which states that a mass at rest tends to remain at rest or a mass in motion continues in uniform motion, at the same speed, unless acted upon by some external force.

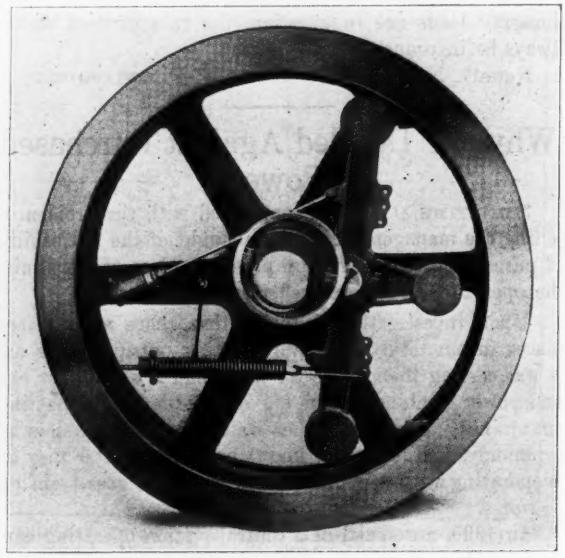


FIG. 2. INERTIA GOVERNOR, WEIGHT ARM, DASHPOT AND SPRING FORMING ESSENTIAL FEATURES

Consequently, there will be a displacement between the flywheel and the weights. This displacement actuates the eccentric attached to the weight arm, shifting the eccentric so that the valve travel is reduced, giving earlier cutoff and thus reducing the speed to normal.

Is the Expansion Valve at Fault?

IN THE ISSUE of Oct. 1 on page 1020, J. M. Hines makes the following statement in reference to the writer's letter in the issue of Aug. 15: "He also recommends a temperature difference of not more than 6 deg. between the brine and the ammonia, carrying the back pressure about 1 lb. higher than the number of degrees indicated by the brine thermometer." The writer has carefully reviewed his letter, and no such absurd statement could be found, nor could any interpretation be made of it to convey such a meaning. The writer said that with ice tanks equipped with accumulators, the best results could be obtained when the back pressure is carried high enough to keep a temperature difference of not more than 6 deg.

F. between the brine and the ammonia evaporating in the coils. Ice tanks not equipped with accumulators usually gave the best results when the back pressure is carried about 1 lb. higher than the number of degrees indicated by the brine thermometer.

Mr. Hines also says that the telltale pipe will show the same tale with only one expansion valve open as it will with a dozen. He has in mind either a system in which two or more ice tanks are equipped with only one accumulator, or a system where each tank has an accumulator but two or more expansion valves, the accumulators having been added to the plant as an after thought. The writer has in mind a system which has an accumulator for each ice tank and only one expansion valve per tank. Also that the accumulator is provided with a drop leg so the liquor line to the expansion valve passes through the suction drum of the accumulator in the shape of a helical coil and then down through the telltale pipe to the expansion valve and discharges into the drop leg. When the tank is sufficiently flooded, the gas coming through the suction drum is wet enough to cool the liquor which is passing through the liquor cooling coil. This will keep the telltale pipe frosted and there is no chance for the telltale pipe to be frosted except from the one expansion valve to which it leads. If the telltale pipe loses its frost there is no other expansion valve affecting it but the one of which it is a part.

In his letter of Aug. 15, the writer did not attempt to give a sure cure for all ailments of accumulators, telltale pipes and expansion valves. He wrote his article in reply to a question asked by a brother operator in the issue of July 1, and made his statements to fit that particular case as it was given.

North Platte, Neb. A. M. CASBERG.

Correct Condenser Operation Prevents Flooding and Starting Trouble

How is water prevented from getting into the cylinders of a cross-compound condensing Corliss engine operating with both barometric and jet condensers, with air pump direct connected to the engine shaft?

2. What is the best and safest method of starting and shutting down such a unit?

3. If I took off some of the turns of wire on a small magnet used on a lost vacuum stop, would I decrease the resistance? If so, I must increase the amperage to make the magnet stronger, but what effect would this have?

L. B.

A. We assume that you wish to know how condenser water is kept from backing up into the cylinders. The question of water coming in through the main steam line will not be discussed here.

Siphon condensers and all condensers of the jet type are generally provided with some form of automatic vacuum breaker, so that in case the condenser should become flooded with the possibility of allowing some of the water to enter the cylinder of the engine or the turbine the vacuum would be broken and the trouble avoided. The possibility of getting water into the cylinder, when using a siphon condenser, is somewhat greater than when using a surface condenser, especially if cooling water is pumped to the condenser head.

If for any reason the overflow or discharge pipe becomes clogged and the water begins to rise in the vacuum chamber it will at a certain predetermined point actuate, by means of a float arrangement, a vacuum breaker which opens the condenser chamber to atmospheric pressure. This of course destroys the vacuum and prevents the further rise of water.

2. The practice in starting up a condensing engine with independent jet condenser varies according to the nature of the load, and the conditions for starting. If an engine has to start under load, the condenser should be started first, so that the power due to the vacuum may be available in helping the engine pull up to speed. If an engine is started without load, it is usually better to start up the engine and let it warm up non-condensing, exhausting through the relief valve to atmosphere, then to start up the condenser and, as the load is thrown on, to put the vacuum on the engine. The engine should not be started up connected to the condenser, with the condenser idle, and vacuum should always be pulled in the condenser before the engine is allowed to exhaust into it, otherwise there is possibility of the water from the condenser flooding back into the exhaust pipe and even reaching the cylinder, which would, of course, be disastrous. Also pressure may be put on the condenser and burst it.

In shutting down, the engine should be shut down first, so that the engine will stop while there is still vacuum on the exhaust system, to keep water out of the exhaust pipe and cylinder. After the engine is stopped, the condenser can be stopped and the vacuum broken, if desired. In any case, the supply of injection water should be shut off before the vacuum pump is stopped, so that the condenser will be pumped clear of any surplus of water to avoid danger of getting it into the engine cylinder.

3. Other things neglected, the strength of an electromagnet is proportional to the product of the current and the number of turns. If either of these two factors is increased or decreased, the other remaining the same, the strength of the magnet will be increased or decreased. The current through a magnet coil is directly proportional to the voltage and inversely proportional to the resistance. If the resistance of a coil is decreased by removing turns and the voltage remains the same, the current will increase.

Suppose we have a coil of 1000 turns, the resistance of which is 100 ohms, connected across a 100-v. circuit. The current through this coil will be

$$C = \frac{100}{100} = 1 \text{ amp.}$$

and the ampere turns 1000. This represents a certain field strength.

Now let us remove 200 turns, which will reduce the resistance to 80 ohms.

The current will now be

$$\frac{100}{80} = 1.2 \text{ amp.}$$

The ampere turn will be

$$1.2 \times 800 = 960$$

Thus, in this case, we see that by reducing the number of turns, although the current is increased, the strength of the magnet is decreased.

The foregoing, however, must not be considered a general statement, as with a coil of different ratios between resistance, turns, current and voltages, the results might be the opposite of what they are here.

EDITORIAL COMMENT

Combined Public Utility and Private Plant Service Shows Possibilities

For many years one of the standard subjects for argument among power plant men has been public utility service versus private plant service. Gradually, however, the economic factors of this problem have resolved into three distinct groups.

Where an organization has use for moderate amounts of light and power but has only a minor use for steam for heating or process work, it is usually admitted that the private plant cannot justify itself on economic grounds. For those organizations using large amounts of low pressure steam for heating and process work and where the steam requirements are reasonably uniform throughout the year or where waste heat is available as in the steel industry, it is usually admitted that the public utility plant cannot compete with the private plant. Between these two groups lies the third class of light and power users such as industries, office buildings, hospitals and institutions where the demands for steam may not be uniform but where power can be produced at a low cost for a part of the year.

Many other factors must, of course, be considered such as value of money at the time of the installation, reserve capacity required to assure reliability of service, increased supervisory responsibility, fuel supply and similar points. Those factors are, however, relatively unimportant as compared with the primary economic factor; the low pressure steam requirements.

For that large group between the two extremes the problem is difficult. In many cases the decision has already been made and the private plant is in operation, producing cheap power for a part of the time and high cost power during the rest of the year.

It has been suggested by many engineers that the real economic solution of the problem faced by plants operating under such conditions would be to use central station service during the summer months and to generate energy in the winter months in accordance with the steam requirements.

This seems to be a simple solution of the problem and it would be, if it were not for one stumbling block—the rates for power purchased on a seasonal or emergency basis. In many cases, public utility rates are based on a demand charge or a minimum-use charge, which raises the rates to prohibitive figures, if power is used for a few months of the year. In some cases, the utilities have recognized the possibilities in the combined service and have arranged special rates for this class of business.

It would seem that from the standpoint of most utilities it would be well worth while to build up the summer load business by making attractive rates to plants in which the steam requirements drop off during the warm months. In many cases the summer peak load of the central station is far below the winter load, due mainly to reduction in domestic consumption. The added load from private plants would partly offset that loss of business.

Many private plant engineers have come to the conclusion that the public utilities have only one idea in view—to drive out such plants regardless of economic considerations. If the utility would go to the industrial organizations with a fair proposition to take over part of the load without attempting, by supersalesmanship or by garbling the facts, to drive the plant out of existence, it would aid in overcoming the present distrust.

There are many interesting possibilities in the relation between public utility plants and private plants. In addition to combined service, there is the question of interconnection and interchange of power but that is a separate problem with many ramifications. The entire subject deserves continued study; it is not a dead issue, as many public utilities would like to believe, but is one of recurring importance depending upon changes in the economic factors affecting industry.

Instruments Are for Those Who Can Use Them

Once in a while, yes, quite frequently, we visit power plants where modern instruments are installed but some of them are out of commission and remain so indefinitely, with apparently no effort on the part of the engineer to put them into service. Instruments out of service are worse than useless; they are a dead expense and, if out of order, sometimes even dangerous when operators depend upon the readings thinking they are correct. The management which permits such conditions to exist deserves severe criticism. Instruments are either reliable or unreliable, useful or not useful; any engineer may make a mistake in his selection of instruments but in any event he should either keep them in use or throw them out entirely.

Another class of power plant managers demands that instruments be kept in perfect order and requires the most elaborate system of records kept, yet when the reports are turned in, the records are filled and seldom, if ever, used to better plant conditions. Can anybody imagine why a power plant should be equipped with instruments for the purpose of piling up records for historic use some centuries in the future? Apparently such managers use instruments principally as ornaments to impress the operating force or the casual visitor with the thoroughness of operating methods employed in the plant.

Perhaps we could get more value out of instruments if we would occasionally consider that they were devised for the sole purpose of imparting information on the changing conditions about the plant. If the operating force and the management cannot make use of information imparted by an instrument, it has no practical value in that plant.

Machinery and instruments cannot do everything in a power plant. Back of the equipment must be human brains directing and controlling operation. This is well exemplified by Howard W. Morgan, who tells in this issue how the heat absorbed by boilers was increased from 59.6 to 73.5 per cent of that in the coal by no other means than the exercise of good judgment in handling the equipment at hand.

Straightening Out the Kinks

In all probability, no power plant has ever been constructed in which some changes have not been necessary before it could be operated to the satisfaction of all concerned. This condition is often greatly misunderstood by those who are in charge of construction and initial operation. The result is that a great amount of unjust criticism is heaped upon the heads of the engineers in charge of design.

Reasons for these apparent errors are evident if quick judgment is withheld and the subject given a little thought. The designer has gotten out of the rut of doing things in timeworn ways; he is striving to do things in a better way. He knows that baffling as arranged in a certain old plant has given results of one kind. He is not satisfied, however, and he reasons that certain changes will give more desirable results. He may not be right in all of his deductions but there is a great probability that with the co-operation and patience of the construction and operating crews an improvement can be made.

This is the history of practically all worth while developments. They have not sprung forth from the thought of a single man but rather from the accumulative efforts of the various units of an organization working in unison and harmony.

Recently a great power plant was put into operation. The initial troubles experienced were delayed combustion, leaky steam joints, scaling, corrosion and excessive air leakage through the boiler setting. This does not prove that either the design was faulty or negligently carried out. Nor does it prove that the erection methods were at fault. It simply goes to show that all conditions cannot be specified on paper and that this plant must go through a process of development until the annoying kinks have been straightened out. This has had to be done in every plant which has preceded it.

Satisfactory operation can be accomplished through cooperation and study. It is a process of elimination which can be completed in a comparatively short time and when once completed the many trials will have been forgotten and the entire organization can then point with pride to the advancement which they have made in the science of power plant design and operation.

Off Duty

We have all no doubt, at some time or other, heard of its "raining cats and dogs" or "pitchforks" or some other equally absurd substance. However novel such an experience might be, in our own case we are frank to admit that we have never witnessed a downpour of this type nor are we particularly anxious to witness one. That being the case we cannot, without unduly exercising our imaginative abilities, write an account of a "cat and dog" or "pitchfork" storm. So instead, we are going to relate a few facts regarding ordinary rainstorms—the kind, which, if they occur in April, make May flowers bloom.

Most of us who live in the cities and who are not directly engaged in the umbrella or raincoat business regard rain somewhat as a necessary evil. It takes the crease out of our newly-pressed clothes, makes us wear rubbers, causes our automobiles to skid, and interferes with our outdoor pastimes, generally. While we are often glad to see rain come we are also glad to see it go. After the storm our interest in the rain usually ends.

In looking through a copy of "Tycos-Rochester" a little publication issued by the Taylor Instrument Co., we came across some figures in regard to rainfall in which we believe you may be interested. Have you any idea, for instance, how much a good rainstorm weighs? No? Well, then, let's see whether we can figure it out.

Water, as we all know, weighs just about 62.5 lb. per cu. ft. From this we can easily calculate that water an inch deep weighs 5.2 lb. per sq. ft. 113.25 tons per acre or 72,483.84 tons per sq. mi. Now, an inch of rainfall from a single storm is not at all unusual. On this basis, a single, well-developed thunder storm may release more than four million tons of water. One thunder storm that occurred in the "arid" state of New Mexico in 1916 released not less than 1,600,000,000 tons?

Since the area of the United States is 3,026,790 sq. mi., it follows that an inch of rainfall over the entire nation would weigh 219,292,962,073 tons. The average annual precipitation for the United States, however, is *not* one inch but 27.6 in. Hence, the normal yearly precipitation over this land of ours comes to the respectable total of over six trillion tons. And then they say this country is "dry"!

The average distance that this water falls is approximately 7900 ft. To raise it that distance would require some 5,530,000,000 hp. operating continuously day and night for every day of the year. This is an average of 1827 hp. per sq. mi. or 2.7 hp. per acre.

Putting it another way, if we were to perform the same amount of work that is done by the sun in raising the moisture which contitutes our rainfall, a 3-hp. engine would be required on every acre of land in the United States, and these 1,937,145,600 engines (18 for every man, woman, and child in the country) would have to be kept running continuously.

Even these figures, however, do not represent the total energy expended by the sun in raising our annual allowance of water, for, while it is raised some 7900 ft. above the land, the average elevation of the land is about 2300 ft. above sea level, and most of our precipitation is raised from the surface of the ocean. So we must add these 2300 ft. to the 7900 ft., whereby the total energy used by the sun in evaporating and transporting our yearly quota of moisture amounts to not less than seven billion horsepower operating continuously throughout the year. This water, if inclosed in a circular reservoir 41 mi. in diameter, would have a depth of one mile.

If the average precipitation for the entire earth is 30 in. (which is not far from correct) then the work done by the sun in raising the water to supply the earth with rain amounts to 176,956,000,000 hp. operating without intermission.

POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS

Power for Seattle from Skagit River

TWO 30,000-KV.A. UNITS AT GORGE PLANT GO INTO OPERATION. FUTURE PLANS CALL FOR 550,000-HP. DEVELOPMENT IN TWO PLANTS

WHEN the first section of the Gorge plant of the Skagit River project went into operation several weeks ago, it marked the completion of the first step in an ambitious scheme for water power development which has been undertaken by the City of Seattle, Wash. The estimated potential capacity of the Gorge and Ruby plants of this development is 550,000 hp. which places the project on a par with Muscle Shoals should the dream of the city materialize.

Even the present project is of sufficient magnitude to involve real engineering problems as the initial rating of the Gorge plant is made up of two 30,000-kv.a. 11,000-v. generators and involved the erection of a dam 240 ft. high with a crest length of 600 ft., and a tunnel 23 ft. 6 in. in diameter and 11,000 ft. long had to be blasted out of solid granite to carry the water to the power house. Six such units will make up the ultimate Gorge plant and the plans for the Ruby plant call for the installation of six 45,000 kv.a. 11,000-v. units.

UPPER THIRD OF RIVER TO BE DEVELOPED

In its length of 150 mi. the Skagit River drains an area of 3000 sq. mi. and finally flows into Skagit Bay, some 50 mi. north of Seattle. The power project is to develop the upper third of the river with a drainage area of about 1200 sq. mi. Stream flow records for the past 12 yr. show that the average precipitation is 70 in. a year; maximum flow is 50,000 sec. ft.; minimum flow is 800 sec. ft. and the mean flow is 4547 sec. ft.

In the scheme of development the first step has been the building of a dam near the mouth of Gorge Creek and a power house located just above the mouth of Ladder Creek. Although the dam will, when completed, back up the water for 6 mi. and give an operating head of 375 ft., the water wheels are now being operated with a head of 270 ft.

A tunnel of horseshoe section with a finished diameter of 20 ft. 6 in. carries the water from the dam to the plant, a distance of 11,000 ft. Connection is made from the

FIG. 1. WATER IS CARRIED TO THE PLANT THROUGH A 20-FT. TUNNEL 11,000 FT. LONG CUT THROUGH GRANITE

main tunnel to each turbine by a steel penstock 10 ft. in diameter, controlled at the lower end by a balanced valve.

At the present time two vertical water turbines rated at 37,500 hp. and guaranteed for 93 per cent efficiency at the full head of 375 ft., are installed in the power house. At the reduced head these two wheels develop 56,000 hp. S. Morgan Smith turbines are installed. The generators and other electrical equipment were supplied by the Westinghouse Electric & Mfg. Co. Generators are rated at 30,000 kv.a., 90 per cent power factor and generate 11,000-v., 60-cycle, three-phase current.

Transmission Is at 165,000 V.

Single phase transformers connected delta Y, raise the voltage to 165,000 and it is fed into Seattle over transmission lines at that voltage. The transmission distance to Seattle is 100 mi. and a right of way 300 ft. wide has been acquired. It is expected that four lines will be built to handle the ultimate development. The single line of three 477,000 cir. mils aluminum cables, steel reinforced, carried on "H" frame wooden poles 55 ft. to 70 ft. high, now handles the output of the two generators. The conductors are placed in a horizontal plane with 15 ft. spacing and are carried by 10 standard Westinghouse insulators in suspension and 12 to 14 high strength units in strain positions.

At the present time the power house building is laid out for three turbine units although it is expected that six such units will be installed when the project is completed. The cost of the first installation was $9,700,000, or $175 per hp. When the third unit is added and the masonry dam is completed, $4,000,000 more will be added to the cost but the cost per horsepower will drop to $122. The cost of the entire project which includes the development of the Ruby dam and power house has been estimated at $57,000,000, or $103 per hp.

Plans for the second development of the project call for the erection of a masonry dam on the Skagit just below the mouth of Ruby Creek about 11 mi. above the present Gorge Dam site. The proposed dam is to be 480 ft. high with a crest length of 1000 ft. The tunnel in this case is to be 28 ft. in diameter, 3¼ mi. long and lined with concrete. This will give a capacity of 6000 sec. ft. at 10 ft. per sec. flow. The surge chamber will be excavated in rock as was also the case in the Gorge plant.

It is expected that the six vertical turbines for this plant will be rated at 55,000 hp. each, at the normal head of 650 ft. The head will, however, vary from 470 ft. to 720 ft. There will be six such units.

Erection of the Ruby dam will create a storage reservoir of 1,300,000 acre feet capacity which will extend 23 mi. above the dam. The creation of this storage will increase the output of the Gorge plant and will mean that the ultimate development of that plant can be handled on a basis of effective water utilization.

In addition to the Skagit River project the city of Seattle also operates the Lake Union plant in Seattle. This is a steam plant equipped with three Allis-Chalmers turbo-generators with a total rating of 30,000 kw. The plant is being enlarged at the present time.

As an auxiliary power supply the Lake Union station also has a Pelton water wheel driving a 1500-kw. Westinghouse generator. This unit is driven by the overflow water from the Volunteer Park reservoir and so makes use of a considerable amount of water that would otherwise be wasted.

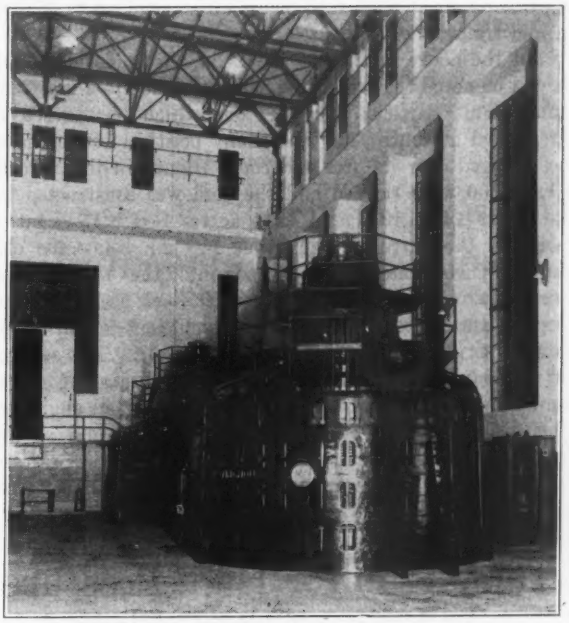


FIG. 2. TURBINES ARE DESIGNED FOR A 375 FT. HEAD ALTHOUGH OPERATING AT PRESENT UNDER A 270-FT. HEAD

Cedar Falls Plant Also Operated by Seattle

Another plant operated by the city is the Cedar Falls generating station, located on the Cedar River about 40 mi. from Seattle. Water is stored for power purposes in Cedar Lake by means of a rock-filled dam approximately one-quarter of a mile below the lake across Cedar River, raising the original elevation of the lake from 1530 ft. to 1548 ft. above sea level and furnishing approximately 16,000 acre feet of storage. The Cedar River masonry dam is located about 1½ mi. down the stream from the timber crib dam.

Water is taken from the timber dam through one 68 in. and one 79 in. wood stave pipe approximately 4800 ft. down the river valley, at which point the two pipes joint into a 78-in. pipe which delivers water into the tunnel leading from the masonry dam to a point 1500 ft. further down the stream. At times of high water this tunnel is fed directly from the pool back of the masonry dam through appropriate gates. At the lower end of the tunnel one 49 in., one 68 in. and one 78 in. wood stave pipes lead to a point on the hill above the power house a distance of approximately 5500 ft. At that point the 49-in. wood pipe joins a 48-in. steel pipe and the 68-in. wood pipe divides into two 48-in. steel pipes, while the 78-in. wood pipe is continued by a 78-in. steel pipe to the power house.

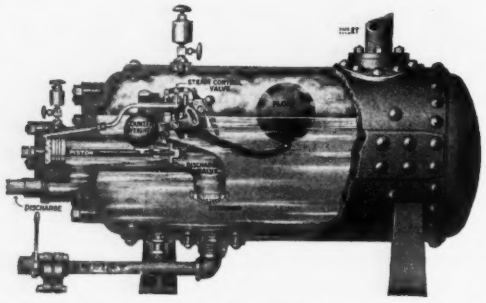
The power house, located at an elevation of 946 ft. above sea level, contains five generating units; one 14,200-kw. driven by an 18,000-hp. Pelton reaction turbine; two 4000-kw. each driven by an 8000-hp. Platt Iron Works reaction turbine; and two of 1200 kw., each driven by 2400-hp. Pelton impulse wheels. The total capacity for the power house is 24,600 kw. The largest unit, which was the last one installed, generates at 6600 v., 3 phase;

the other four at 2300 v., 3 phase, all stepped up to 66,000 v. and transmitted to Seattle.

In the above outline of the Cedar River development it will be noted that reference has been made to a masonry dam. This particular dam is one which has caused a great deal of controversy and many political battles have been waged over its pros and cons. Bonds in the sum of $1,400,000 were ratified and the dam was constructed in the years 1912, 1913 and 1914 across Cedar River at a point in the narrow gorge about 1½ mi. below the old dam. When water was turned into the reservoir, a seepage from the north bank, which had been in some degree anticipated, developed, of sufficient quantity to impair seriously the value of the reservoir. The sealing of this bank which consists of a glacial moraine of gravel and sand with practically no clay, presented an engineering problem which has not yet been solved and at the present time, the dam is useful only to conserve a certain portion of the flood waters and to insure the timber dam at Cedar Lake against washout by flood.

Tank Trap for High Pressure Is Built of Steel Plate

UNDER the name of the "Nicholson" super-trap, tank type, a new design of steam trap has recently been placed on the market by W. H. Nicholson & Co., Wilkes-Barre, Pa. The general principles underlying this design are similar to those employed in previous traps produced by this company, except that it has been developed to accommodate high pressures.



TRAP IS BUILT TO WITHSTAND WORKING PRESSURES OF 600 LB. AND TEMPERATURES UP TO 700 DEG. F.

The present model has been designed under Boiler Code Rules for a working pressure up to 600 lb. per sq. in., maximum temperature 700 deg. F, with a capacity of 25 gal. per discharge, or an hourly capacity of 175,000 lb., but this quantity may be increased to suit specific requirements. The body of the trap is constructed of riveted steel plate and is furnished with inlet, outlet and blowoff connections. One end is fitted with a cast steel cover to which is attached the operating mechanism. By removing this cover all working parts are exposed for examination or repair.

Positive action of the discharge valve is obtained by a piston working in a cylinder in the cover casting. Steam is admitted to the cylinder by a small pilot valve of the poppet type which is opened by a falling weight, released by means of a special high pressure float, at the instant that the condensate reaches a predetermined height in the trap. A special device holds the pilot valve open during the whole period of discharge so that wiredrawing is entirely eliminated. The discharge valve opens instantaneously and remains open until a complete discharge has been effected, when it instantly closes.

Valves, valve seats and all wearing parts are of monel metal, and are easily renewed. The complete apparatus is mounted on a cast-iron stand ready to connect to the pipe line.

New Steam-Driven Pumping Plant for Chicago

ON Sept. 1 work was started on a new pumping station for the City of Chicago to be located at 49th Street and Western Avenue. This station will have a maximum capacity of 300,000,000 gal. a day against a total head of 150 ft. No expense will be spared to make it the most modern and efficient pumping station in the world. The total cost of the station proper will be about $3,000,000 and it is expected that it will be in operation by September, 1927.

Water will be brought from the Edward F. Dunne crib, about 2 mi. out in Lake Michigan, through a tunnel about 11.5 mi. long. About 6 mi. of this tunnel is new work, started in 1919 and completed in 1924. The new part of the tunnel is of an approximate horseshoe section 12 ft. in diameter, and cost about $4,500,000. This tunnel was driven entirely through rock.

In laying out the plant a unit system of design was adopted, so that each of the four DeLaval turbine-driven geared centrifugal pumps will be served by a separate 600-hp. Edge Moor four-pass boiler, fired by the latest type of Taylor stokers. Each unit can be operated independently in case of breakdowns or fluctuations in the load.

Operating steam pressure will be 325 lb. gage, with 225 deg. superheat. The boilers will be operated at from 100 to 200 per cent of rating. All auxiliaries will be driven by direct-current motors, the current being obtained from a generator driven by a non-condensing turbine. Steam will be bled from the main turbines to heat the boiler feed water to 210 deg.

Stokers, which will be built by the American Engineering Co. of Philadelphia will have six retorts each and will be 21 tuyeres deep, with a power ashdump and individual motor drive, the motors being mounted on the stoker power boxes. These stokers were chosen with a view to burning low-grade fuel from the Indiana and Illinois coal fields.

Coal will be dumped from cars into a track hopper, crushed and elevated to reinforced concrete overhead storage bunkers. From the storage bunkers, the coal is weighed and delivered to the stoker hoppers by larries. Ashes will be handled by cars and a skip hoist to an overhead hopper, from which it may be removed by truck or railroad cars. The stack is of radial brick, 9 ft. in diameter at the top, and 184 ft. above the boiler room floor.

Design, construction and operation of the Chicago water supply system is under the direction of John Ericson, who has been city engineer for 26 yr. Myron B. Reynolds is assistant city engineer; Loran D. Gayton, engineer of water works design; and James J. Versluis, engineer of water works construction.

Power Show to Feature Lectures

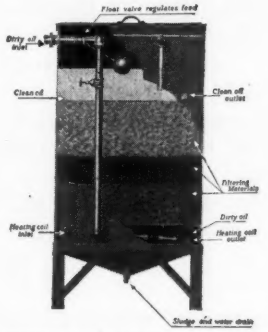
ONE feature of the third National Exposition of Power and Mechanical Engineering will feature a series of lectures on recent developments in important phases of power-plant and mechanical engineering practice. The exposition will be held in the Grand Central Palace, New York, from Dec. 1 to 6, 1924, and the lectures will be held in the assembly hall at times that will not conflict with the more formal papers presented at the annual meetings of The American Society of Mechanical Engineers and The American Society of Refrigerating Engineers which parallel the first four days of the exposition.

Several schools of mechanical engineering will send delegations of students and instructors to the exhibition and a series of lectures is planned to give the students, and any others who may be interested, a complete picture of recent developments of power plant and mechanical engineering practice with the exposition as a background. The lectures will be supplemented with visits to the various exhibits. The topics selected are: The Boiler Room, Steam Prime Movers, Oil and Gas Engines, Hydroelectric Power Plant Equipment, Materials Handling, Modern Machine Tool Developments, Mechanical Power Transmission, Mechanical Refrigeration, Heating and Ventilating.

Exhibits, which will occupy 150,000 sq. ft. on three floors of the Palace, will include a complete showing of all lines of power plant apparatus and accessories, materials handling equipment, and many showings of heating and ventilating apparatus, refrigerating machinery, machine tools, and machine shop equipment.

New Oil Filter Is Brought Out

ONE of the new developments of the Bousman Manufacturing Co. of Grand Rapids, Mich., is a power plant oil filter of the continuous and batch types. The principle of this filter is that which has been employed to meet severe conditions in industrial filtration problems,



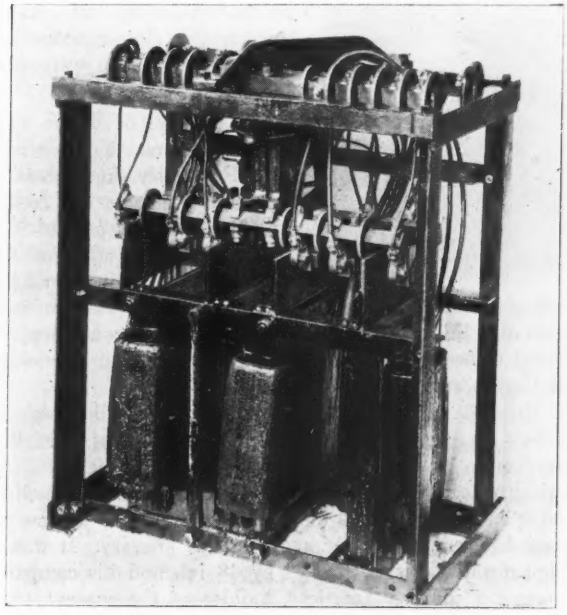
FILTER MAY BE USED FOR BATCH OR CONTINUOUS SERVICE

and the advantages claimed are: Long intervals between cleaning; easy removal of water and most dirt before these impurities get into the filtering materials; thorough filtration, yielding a product free from suspended impurities and water; and simple and dependable continuous action providing a flexibility of output to meet sudden or intermittent demands for clean oil.

The principle employed is that of up filtration through from 3 to 6 cu. ft. or more (according to the size required) of filtering materials. This allows water and the heavier suspended matter to settle into a receptacle at the bottom of the filter, from which it is drawn as a sludge, before it can come in contact with the filtering materials. This, combined with the large amount of filtering material, allows the filter long periods of effective operation between cleaning and repacking periods.

Automatic Compensator for High Voltage Is Developed

DEVELOPMENT of an automatic high voltage compensator has recently been announced by the Electric Controller & Manufacturing Co. of Cleveland, Ohio. This compensator is built for voltages 2500 and below. It is push button operated and entirely automatic. With the



WORKING MECHANISM OF AUTOMATIC COMPENSATOR FOR VOLTAGES UP TO 2500

exception of the overload panel, which is mounted on the top of the tank, the compensator is submerged in oil and the tank is so designed that the compensator is said to be dust-proof, weather-proof, vapor-proof and fire-proof. It can be installed either indoors or outdoors. A push button is operated by an independent low voltage circuit which is taken from an independent transformer so that there is no danger of the operator coming into contact with the high voltage circuit.

Having the starting transformers and the operating mechanism entirely submerged in oil and automatically operated removes possibility of explosions or high voltage flashes. This automatic compensator is so designed that continuous torque is applied to the motor from the time the push button is pressed until the motor has been brought up to speed.

Operating the start switch causes the motor to be started under reduced voltage, obtained from the transformers in the compensator and after the motor has reached the proper and safe speed it is automatically thrown across the line by the compensator.

Engineering World Suffers Loss in Death of Nordberg

WHEN DEATH claimed Bruno V. Nordberg on October 30, the engineering profession lost the services of a man who was always willing to undertake development projects of type which critics declared to be impractical. As a result of this fearless engineering attitude Nordberg contributed much to engineering progress, particularly in the fields of engine, compressor and hoisting equipment manufacture.

Bruno V. Nordberg was born in Finland, April, 1857. His father, Carl V. Nordberg, operated a shipyard in Finland, having had experience with fast sailing ships in the United States, India and China. He was himself a sea captain and an ardent admirer of the American Merchant Marine, the clipper ships of which at that time were the finest in the world.

At the age of 21 he was graduated from the Helsingfors University and shortly afterwards came to this country. It was his purpose to follow shipbuilding, strongest of his boyhood ambitions, and he settled in Milwaukee. His first job, however, was drafting with the E. P. Allis Co. and within a year he stepped ahead to become the right-hand man of Edwin Reynolds, of Corliss engine fame.

In 1889, with a force of six men, Mr. Nordberg established his own concern, centering his efforts upon the production of a successful cutoff governor, which, with a variable load, effected a large economy over plain slide valve engines. In 1892 he built his first steam engine, to meet a special order for a Milwaukee brewery. It was a poppet valve design, size 24 by 48 in., and his company became a pioneer American builder of the present type of poppet valve engine. Subsequently he took up the manufacture of pumps, Corliss engines, hoists and compressors. He improved the Corliss engine, in various ways, made the engine frame in one piece and invented the full stroke valve gear.

In 1899 he designed a pumping engine with a new steam cycle which achieved noteworthy results and by which the efficiency of a steam engine was increased beyond the limits that heretofore were considered attainable. In 1900, he was the first manufacturer to install individual shop motor drives on a large scale.

He early gained the confidence of the mining men in the copper mines of the upper Michigan peninsula, due to his ability to solve successfully problems related to mining machinery, and for a number of years his time was largely devoted to designing efficient hoisting, pumping, compressing and stamping machinery for this district. To meet the requirements of this locality, Mr. Nordberg designed an extremely large cylindro-conical drum hoist, which became a standard design.

During the war Mr. Nordberg directed his efforts toward quantity production of 1400-hp. vertical triple expansion engines to equip the new ships of the Emergency Fleet Corporation, and in designing special compressors for inflammable gases and machinery for liquefying gases.

For the past 30 years Mr. Nordberg has been an active member of the American Society of Mechanical Engineers, contributing many papers and discussions to its transactions as well as other technical journals.

Many Power Subjects in A. S. M. E. Program

WHEN the annual meeting of the American Society of Mechanical Engineers takes place in New York on December 1st to 4th, engineers who are interested in power plant problems will listen to a number of papers dealing with this phase of engineering. Fuel oil will come in for more than usual attention, both from the standpoint of handling such fuel as well as burning it efficiently. Steam power, oil engine power and hydraulics will also be covered.

An innovation at this year's meeting will be the insertion of two lectures, one on Tuesday, December 2 and the other on Thursday, December 4 and set for delivery at 4:30 p. m. so that all of the members attending special sessions can be present. The Tuesday lecture, presented by Julian D. Sears, will cover the "Petroleum Situation in the United States" and on Thursday, P. W. Bridgman will talk on "High Pressures."

In addition to the papers on power problems, there will also be several important sessions for members who are interested in the engineering problems of the machine shop. The social program has also been carefully planned. It will differ from those of former years in that the president's reception will be held on Tuesday evening and there will be a dinner on Wednesday evening at which new members of the society will be presented to the society.

Papers to be presented which will be of particular interest to the power industry are as follows:

Tuesday, Morning, December 2

Storage and Handling of Fuel Oil in Industrial Plants, C. G. Sheffield, and H. H. Fleming, Standard Oil Co.

Handling Oil from Storage to Furnace, John R. Battle, president, J. R. Battle Co.

Tuesday Afternoon

The Flow of Fluids, W. H. McAdam.

Law Governing Temperature at Which Liquid Evaporates Into Gas, W. H. Carrier, Carrier Engineering Co., and D. C. Lindsay.

The Zoelly Turbine-Driven Locomotive, Henry Zoelly.

Wednesday Morning.

Oil Burning in United States Navy, Lt.-Commander H. G. Donald.

Oil Burning in Central Station Service, N. E. Lewis, Babcock & Wilcox Co.

Hazards of Industrial Oil Burning, H. E. Newell.

Critical Bearing Pressures Causing Ruptures in Lubricating Oil Films, Lt.-Commander L. N. Linsley.

High-Pressure Bearing Research, Louis Illmer.

Graphical Study of Journal Lubrication, H. A. S. Howarth, Kingsbury Machine Works.

Thursday Morning

Water Treatment for Continuous Steam Production, R. E. Hall, U. S. Bureau of Mines.

The Increase in Thermal Efficiency Due to Resuperheating in Steam Turbines, W. E. Blowney and G. B. Warren.

Review of Recent Applications of Powdered Coal to Steam Boilers, H. Kreisinger, Combustion Engineering Corp.

Recent Developments in the Burning of Anthracite Coal, W. A. Shoudy, Adirondack Power & Light Co., and R. C. Denny.

Thursday Afternoon

Solid-Injection Oil Engines, R. Hildebrand, Fulton Iron Works.

The Double-Acting Oil Engine, C. E. Lucke, Columbia University.

Gas Turbines, L. S. Marks, Harvard University, and M. Danilov.

Methods of Economic Design of Penstocks, H. L. Doolittle, Southern California Edison Co.

Study of Draft Tube Design, Robert Angus.

News Notes

R. C. BROACH has been appointed southeastern district manager with offices at 709 Glenn Building, Atlanta, Georgia, of the Heine Boiler Co.

MARION MACHINE, FOUNDRY & SUPPLY Co. of Marion, Ind., has opened a New York City office at 116 West 39th St. in charge of W. H. Caldwell. This office will handle sales and service in the metropolitan area.

ADDITIONAL AIR WASHING and cooling equipment is to be installed in the Adolphus Hotel, Dallas, Texas, at a cost of $60,000, according to J. L. Rowder, chief engineer. Ophus & Hill, Inc., consulting engineers of New York City, will handle the installation.

BETSON PLASTIC FIRE BRICK Co., Rome, N. Y., is establishing a factory at 82 Dock St., St. Louis, Mo., to handle the Mississippi Valley trade. W. F. Schroeder, Joseph M. Curry and George C. Probst of the firm Schroeder & Curry, Combustion & Sales Engineers, are the active executives of the new plant.

GEORGE H. SMITH, formerly with Sharpsville Furnace Co., Sharpsville, Pa., has taken a position as chief engineer and master mechanic with the Tonawanda Iron Corporation of North Tonawanda, N. Y. This is the blast furnace plant formerly owned by Donner Steel Co. of Buffalo, N. Y. The new corporation is practically reconstructing the entire plant.

FIDALGO LUMBER & BOX Co., Anacortes, Wash., has just completed and cut-in the new 1560-kv.a. Westinghouse steam turbine, housed in a special reenforced concrete two-story building 28 by 32 ft. designed by Superintendent T. B. Morrison. This building also houses a General Electric 75-kw. turbine used for lighting load, as well as the Alberger condensers. This plant was designed and installed by Wm. L. Smith, chief engineer.

RECENTLY THE Worthington Pump & Machinery Corp. completed a 30-day non-stop test run on the new double-acting two-cycle Diesel engine which was described in the Sept. 15 issue of Power Plant Engineering. The single-cylinder unit showed a fuel consumption of 0.428 lb. per b.hp.-hr. with an oil of 28 to 32 deg. Baume. The average brake horsepower was 615 at 89.9 r.p.m. After the test run was completed the engine was inspected by a number of engineers of the U. S. Shipping Board, the Navy department and large private interests. It is the expectation of the company to build this engine in ratings up to 5600 hp. at 125 r.p.m. in six cylinders. Even higher ratings will be furnished if the demand requires them.

WOLFORD TANK Co. of Darby, Pa., is installing a new power plant, consisting of two 150-hp. Keeler boilers, one 150-kw. Erie Ball engine, one 75-kw. Harrisburg engine, two Crocker-Wheeler generators and a Cochrane heater. Piping contract to Machold & Riddell, Philadelphia. The plant is to be completed about Feb. 1, 1925.

E. K. WOOD LUMBER Co. mill at Anacortes, Wash., has just completed an installation of one 1250-kw. General Electric steam turbine, following a plan to electrify all of its mills. Another similar turbine has been in operation at the Anacortes plant since it was built; so it is expected that when the planing mill is added to the saw mill at this plant these two generating units will be able to handle the load. Installation of this latest unit was under the supervision of M. H. Blake, chief engineer of the Anacortes plant.

W. N. DURBIN, former president, and R. I. Van Winkle, former secretary of the Anderson Foundry & Machine Co., associated with Jos. E. Hennings and Linfield Meyers, Anderson bankers, have incorporated the National Engineering & Equipment Co. of Anderson, Ind. They will specialize in power equipment and kindred lines with special attention to plant design and construction, as well as equipment for brick and clay working plants, crushing and pumping plants for the stone, sand and gravel industries.

FINAL PUBLIC HEARING on the Mechanical Refrigeration Safety Code, formulated under the direction of the American Engineering Standards Committee and the sponsorship of the American Society of Refrigerating Engineers, will be held in Room 1001 of the Engineering Societies Building, 29 West 39th St., New York, N. Y., on the afternoon of December 1, 1924, at 2:00 o'clock. Copies of the Code in the form in which it will be presented at this hearing will be available about November 15, 1924, and may be secured by writing to the American Society of Refrigerating Engineers, 35 Warren St., New York City.

Books and Catalogs

INDUSTRIAL ELECTRICITY, by Chester L. Dawes; 363 pages, 6 by 8 in., cloth, 1924. Price, $2.25.

Industrial applications of electricity are increasing in diversity and number rapidly so that more and more is it becoming essential for the owner of a business or the manager of an industrial plant to have an understanding of the operation of electrical machinery. This book, Part I, is designed to give such an understanding of the principles and of the operation of generators, motors and batteries. Chapter heads give the best idea of the ground covered. They are: Magnets and Magnetism; Electromagnetism; Resistance; Ohm's Law and the Electric Circuit; Battery Electromotive Forces; Primary and Secondary Batteries; Storage Batteries; Electrical Instruments and Measurements; The Magnetic Circuit; Electrostatics and Capacity; The Generator; Generator Characteristics; The Motor; Losses, Efficiency, Operation. For each chapter there is a series of questions and problems to test the understanding of the reader and his grasp of the

text. Illustrations are clear and for the most part specially prepared to accompany the reading matter. The language is simple and such mathematics as is used, nothing above simple algebra, is directly to the point. Particularly good is the clear treatment of the magnetic circuit and the way that it enters into electrical machinery. But the whole book can be commended to anybody who is seeking an understandable introduction to the action of electrical machinery.

BULLETIN No. 103 of the Standard Water Systems Co. of Hampton, N. J., describes the multi-coil type feed water heater giving its advantages and contains the diagram and table giving dimensions of the various sizes.

FOOS OIL ENGINES, type R, are described in bulletin No. 704, issued by the Foos Gas Engine Co. of Springfield, Ohio. These engines range in rating from 30 to 400 hp. and are of the Diesel type with airless injection of the fuel oil into the combustion chamber.

OILS AND THEIR FILTRATION is the subject of a new bulletin published by the Bousman Mfg. Co. of Grand Rapids, Mich. The bulletin describes the Bousman line of oil filters and shows how these are applied for either the batch or continuous system.

HANDY WIRING TABLES AND ILLUMINATING DATA, third edition, revised, is now being distributed by the Westinghouse Electric & Mfg. Co. This is a 52-page booklet of practical information for those interested in the more efficient use of electricity for lighting, power and industrial purposes.

IN A BOOKLET ENTITLED "CONDENSATION," the Crane Co., 836 S. Michigan Ave., Chicago, has presented considerable information on the use of traps. In addition to describing the Crane traps, numerous drawings are used to show the application of such traps in various classes of service.

SMOKE ABATEMENT is the title of a 320-page book by L. H. Cannon of the St. Louis Public Library. It is a resume of the police power in various cities of the United States as embodied in laws, ordinances and court decisions. The book presents a comprehensive compilation of available information on the question of abatement of smoke in the more densely populated districts. Representative laws and ordinances are quoted and numerous court decisions which have been handed down on this question are recorded.

NATIONAL SAFETY COUNCIL has prepared for 1925 a most attractive calendar with reproductions of oil paintings at the head of each monthly sheet. On the back of the sheet is a set of cautions and directions for avoiding accidents and giving first aid treatment in emergencies, covering most of the situations which are met in ordinary business and industry. This calendar is available at nominal cost to the public, further information being obtainable from National Safety Council, 168 North Michigan Ave., Chicago, Ill.

CARBON CIRCUIT BREAKERS, Type CL, for Industrial Applications is the title of a new 24-page publication issued by the Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa. This circular describes carbon circuit breakers designed for use on 250-v. industrial systems, but which may be used on 600-v. lines if barriers are placed between the poles. A thorough description of the construction and of the principles of operation of the new CL breaker is supplemented with cuts and drawings showing the various types and applications of CL breakers.

Several new features in breaker design have been incorporated in this new protective device. Among them are: adjustment of brush pressure, one-piece frame construction which makes installation easy, unit construction, permitting the addition of various attachments without difficulty.

Attachments, such as, the inverse-time limit overload, the shunt trip, the under-voltage release, and the reverse current attachments are all easily added to the plain overload breaker in the field, and single-pole units can be combined in the multi-pole breakers without great change.

DIEHL MOTOR-DRIVEN EXHAUST FANS is the subject of bulletin No. 1650, published by the Diehl Mfg. Co., Elizabeth, N. J. Fans of the type described are used in ventilating work.

CENTURY POLYPHASE INDUCTION MOTORS of the squirrel cage type, varying in rating from 1/6 to 75 hp., are described in a bulletin now being distributed by the Century Electric Co. of St. Louis, Mo.

BOLINDER'S CO., INC. of Stockholm, Sweden, is distributing a bulletin from its New York City office, 30 Church St., on the company's model N stationary heavy duty oil engines. This engine is of the two-cycle semi-Diesel type and is built in ratings of 400 hp. at 300 r.p.m.

"COAL HANDLING EQUIPMENT" is the subject of booklet No. 32 now being distributed by the Orton & Steinbrenner Co., 608 South Dearborn St., Chicago, Ill. The bulletin shows various applications for locomotive type cranes and the different forms of mountings for such cranes.

MECHANICAL RUBBER GOODS is the subject of a 200-page catalogue which has recently been issued by the New York Belting & Packing Co., 91 Chambers St., New York City. The catalogue contains much useful information, describes the different lines of goods made by the company, gives list prices and also presents facts concerning the use for these products.

THE LUNKENHEIMER CO. of Cincinnati, Ohio, has issued a folder which illustrates application of Lunkenheimer boiler mountings conforming to the A. S. M. E. boiler code specifications. A drawing of a horizontal return tubular boiler shows the various fittings and these are given a key number which refers to a tabulation showing the A. S. M. E. requirements for such fittings.

AUTOMATIC STATION CONTROL EQUIPMENT, a 27-page bulletin designated as No. 47,731, has recently been issued by the General Electric Co., of Schenectady, N. Y. It describes briefly the uses and advantages of this type of equipment. The greater part of the bulletin is given over to a list of installations up to January 1, 1924, giving the name of the company, station, type of apparatus, kilowatt capacity and incoming and outgoing voltage.

A NEW METHOD OF CUTTING double helical gears through the use of the Sykes gear cutting machine is described in a folder now being distributed by the Farrel Foundry & Machine Co., of Buffalo, N. Y. This machine cuts double helical teeth without a gap at the center and the helical angle may be changed as desired. Gears of this type are used as reduction gears on turbines and the Farrel Organization cuts the gears and is also distributing the Sykes machine.